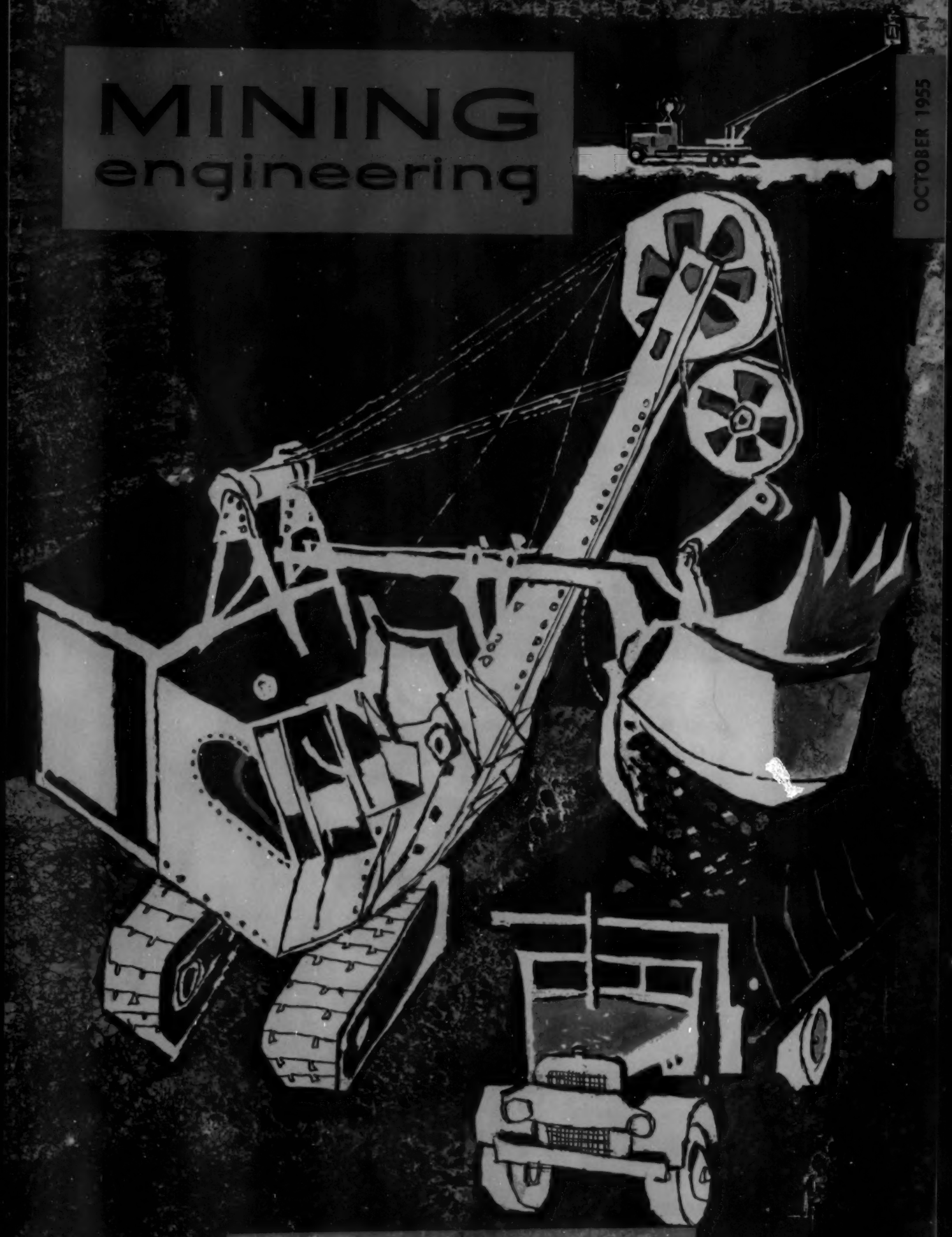
MINING engineering

OCTOBER 1955



Quebec's new cement plant chose

WILFLEY SAND PUMPS

for GREATER DOLLAR SAVINGS
IN OPERATING and MAINTENANCE COSTS

The Wilfley Pumps shown here are a cost-reducing factor of major importance in the huge, $13,000,000 wet-process plant at Quebec City. This installation is typical of the highly efficient job Wilfley Pumps are doing in modern cement plants throughout the world. Actual production-line records prove that Wilfley Pumps reduce operating costs, increase production and deliver trouble-free performance. Let Wilfley solve your pumping problems. Individual engineering on every application. Write or wire for complete details.

Wilfley Acid Pump
"COMPANIONS IN ECONOMICAL OPERATION"
Wilfley Sand Pump

A. R. WILFLEY and SONS, INC.

Denver, Colorado, U.S.A. • New York Office: 1775 Broadway, New York City

EDITORIAL STAFF

Manager of Publications: Alvin S. Cohan
Editor: Charles M. Cooley
Associate Editor: Rixford A. Beals
Assistant Editors: Scott Conkling, M. E. Sherman
Eastern Advertising Manager: Warren V. Smith, 29 W. 39th St., New York
Mid-Western Advertising Manager: Bob Wilson, Millard Ave., Fox River Grove, Ill.
Western Advertising Representatives: McDonald-Thompson, 625 Market St., San Francisco 5, Calif.
Production Manager: Grace Pugsley
Asst. Prod. Manager: W. J. Sewing

AIME OFFICERS

President: H. DeWitt Smith
Vice Presidents: T. B. Counselman, W. A. Dean, Harold Decker, L. E. Elkins, A. B. Kinzel, W. W. Mein, Jr.
President-Elect: C. E. Reistle, Jr.
Treasurer: G. F. Moulton

AIME STAFF

Secretary: Ernest Kirkendall
Secretary Emeritus: E. H. Robie
Asst. Secretaries: J. B. Alford, H. N. Appleton, E. J. Kennedy, Jr.
Field Secretary & Asst. Secretary: R. E. O'Brien
Asst. Treasurer: P. J. Apol
Technical Publications Committee: Robert H. Aborn, Chairman; E. J. Kennedy, Jr., Secretary

Divisional Publications Committee Chairmen: H. C. Weed, Mining; H. R. Gault, Geology; Dart Wantland, Geophysics; H. R. Spedden, Beneficiation; Carroll F. Hardy, Coal; R. W. Smith, Indust. Minerals; George B. Clark, Education; H. A. Franke, Mineral Economics;

The AIME also publishes **Journal of Metals** and **Journal of Petroleum Technology.**

Published monthly by the American Institute of Mining and Metallurgical Engineers, Inc., 29 West 39th St., New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $8 per year for non-AIME members in the U. S., & North, South & Central America; $10 foreign; $6 for AIME members, or $4 additional in combination with a subscription to "Journal of Metals" or "Journal of Petroleum Technology". Single copies $.75; single copies foreign $1.00, special issues $1.50. The AIME is not responsible for any statement made or opinion expressed in its publication. Copyright 1955 by the American Institute of Mining and Metallurgical Engineers, Inc. Registered cable address, AIME. New York. Indexed in Engineering Index, Industrial Arts Index, and by The National Research Bureau. Entered as second-class matter Jan. 18, 1949, at the post office at N. Y., N. Y., under the act of March 3, 1879. Additional entry established in Manchester, N. H. Member, ABC.

MINING engineering

VOL. 7 NO. 10 OCTOBER 1955

COVER

Artist Herb McClure found visual excitement in the machines used to move large masses of rock in oil shale mining at Rifle, Colo. The article that intrigued him appears on page 925 of this issue.

FEATURES

Personnel	890	Drift	919
Books	898	AIME News	969
Manufacturers News	895	Personals	976
Reporter	901	Professional Services	982
Mining News	907	Coming Events	984
Trends	914	Advertisers Index	984

ARTICLES

What Is The Economical Point of Replacement of Pit Equipment In The Southwest Copper Pit? B. R. Coil 921

Oil Shale Mining Program Does Two Jobs J. H. East, Jr., and C. K. Rose 925

Development of Monazite Exploration Techniques Improves U. S. Rare Earth Supply Situation R. F. Griffith 930

Mining Engineering Notebook 933

TRANSACTIONS

The Chollet Project, Stevens County, Washington M. W. Cox and V. F. Hollister 937

Requirements of Modern Paper Clays C. G. Albert 941

Agglomerating Fine Sized Ores with Low Temperature Coke C. E. Lesher 944

Analysis of Variables in Rod Milling— Comparison of Overflow and End Peripheral Discharge Mills Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom 949

Analysis of Roof Bolting Systems Based on Model Studies Louis A. Panek 954

Streaming Potential Studies— Quartz Flotation with Cationic Collectors A. M. Gaudin and D. W. Fuerstenau 958

Work of Geochemical Exploration Section of the U. S. Geological Survey T. S. Lovering 963

Magnetic Storm Monitor W. E. Wickerham 966

Discussion: An Agglomeration Process for Iron Ore Concentrates Robert E. Hagen 948

PERSONNEL

THE following employment items are made available to AIME members on a nonprofit basis by the Engineering Societies Personnel Service Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Consultant, age 49, B.S. in mining and E.M. Manager and consultant—mining, milling, exploration. Experience—all mining methods, metallurgy of metals and nonmetallics. Successful in exploration and negotiations. Broad general experience. Prefers U. S. and Continent. M-239-Chicago.

Mining Engineer. Broad experience in uranium, exploration, and development. Twenty years mineral exploration, development, and operation. Employed. M-240.

Engineer, 33, noncitizen, residing Europe. Six years civil engineer; 4 years mining experience including development and exploration. Desires position underground metal mining. Any location. Speaks French and Spanish. Available immediately. M-241.

Chief Engineer, 37, married, 4 children. Experienced in mining field, industrial plant construction, construction coordination, and budget control. Desires responsible position with progressive company in North or West. M-242.

POSITIONS OPEN

Instructor or Assistant Professor, for mineral industries dept., to teach courses in general physical geology, mining engineering, and metallurgical operations. Opportunity for research and personal improvement. Location, South. W1734.

Chemical Mineralogist, well trained in mineralogy and related subjects, preferably with good background in chemistry, to identify and report on minerals, rocks, and ores; to conduct or to direct assistant in making assays for gold, silver, copper, lead, and other elements of commercial importance; to prepare and publish results of studies on minerals. Must be U. S. citizen or have declared intentions of becoming one. Salary, $4800 to $5800 a year. Location, Nevada. W2092.

Project Engineer, metallurgical or chemical graduate, to assist in design and preparation for market, various lines of equipment used in mineral dressing, heavy chemical, cement, and rock product industries. Must have good engineering and field experience and be willing to travel and do field service. Permanent. Location, eastern Pennsylvania. W2027.

Mining Engineers. (a) Engineer-surveyor, mining engineering or geological background, young, experienced, to keep up mapping in bedded deposit mines, plus geological work on surface and underground core drilling supervision. (b) Mining engineer experienced in modern mine mechanization adaptations, knowledge of mining machinery. Will take charge of cost reduction, planning for entire underground operations, three to four small mines. (c) Ore dressing metallurgist, young, to act as mill foreman in fluorspar flotation mill. Opportunity for advancement. Salaries open. Location, Midwest. W2019.

Assistant Mill Superintendent for large base metal mine in South West Africa. Should be technical graduate with at least 5 years base metal flotation experience. Three-year contract, transportation for self and family, and salary while traveling. Furnished home available for married man. Climate and living conditions excellent. F2163.

Mining Engineer, 30 to 35, with strip mining experience in clay, talc, or gypsum fields, including milling and product preparation experience. Salary, $6000 a year. Location, Pennsylvania. W2063.

Plant Engineer, 25 to 35, BSCE, or mining, with experience in connection with quarrying, mining, or processing rock products. Salary open. Location, South. W1775(a).

Mining Engineers wanted for Managers of Tin Mines in Bolivia. 3-year contract, furnished house, lights, and fuel furnished. Passages paid for employee, wife and children. Write Corporacion Minera de Bolivia, Casilla 349, La Paz, Bolivia, sending record and experience, with photo. Must speak Spanish. Salary commensurate with experience.

GRADUATE MINING ENGINEER, age 50, good health, married, 3 children, fluent Spanish. 27 years operational and exploration experience. Familiar with all phases of mechanization as applied to underground mining. Have good record of low costs. Desires position of responsibility.

Box 13-K AIME
29 West 39th St. New York 18, N. Y.

WANTED: Qualified person to take charge of maintenance department, responsible for maintenance and repair of all underground equipment of large coal mining operation. Electrical or mechanical engineer preferred. Anyone interested should contact Inland Steel Company, Wheelwright, Kentucky.

MINING ENGINEER

Cuban Nickel Mine seeking Mining Engineer with thorough knowledge of surveying, drilling, mapping and calculating mining claims. Must have college degree and at least three (3) years experience in related work. Should be able to read, write, and speak Spanish. If interested write direct to:

Nickel Processing Corporation
111 Broadway New York 6, N.Y.

Give full details of education, family status, availability and salary expected.

MINING ENGINEER: To keep abreast mining activities in Nevada, examine new mineral discoveries, give technical assistance to prospectors and small mining operations. Prefer man with 5 or more years' experience in industry. Salary $4,800 to $5,800. U. S. citizen or first papers. Write: Vernon E. Scheid, Director, Nevada Bureau of Mines, University of Nevada, Reno, Nevada.

ELECTRIC SHOVEL FOR SALE

One (1) Model 1400 P&H 4 cubic yard Electric Shovel, 3810/2200 volts, 3 phase, 60 cycle. New 1946. Can be seen in operation and inspected at mine near Atikokan, Ontario.

STEEP ROCK IRON MINES, LTD.
STEEP ROCK LAKE, ONTARIO

Mining Engineer, young, with underground experience, for surveying, mapping, etc., with metal mining company. Salary open. Location, South. W1725.

Mining Engineer, with considerable management and executive ability in the management and operation of a gold and platinum surface mine. Salary open. Northwest. W1748.

Mining Engineer, Geologist, graduate, 35, for planning and assistance on undersea mining program. Must have had actual undersea mining experience and good geological background. One-year contract. Salary, $12,000 to $15,000 plus housing. Location, Foreign. C3632.

Equipment Supervisor, preferably with engineering training and plant engineering experience covering maintenance of mining equipment. Salary, $6000 to $6500 a year. Location, South. W1772.

Engineers. (a) Research process metallurgist, master's or doctor's degree in metallurgy, with up to 5 years experience, for research and development in nonferrous extractive metallurgy in research dept. of nonferrous mining and smelting company. Pyrometallurgy, roasting, smelting, process research for production of nonferrous metals, including titanium. (b) Research physical metallurgist, master's or doctor's degree in physical metallurgy with up to 5 years experience for research in product development group of research dept. for producer of nonferrous metals and alloys, alloy development, metal finishing, corrosion and electrochemical research. Location, East. W2053.

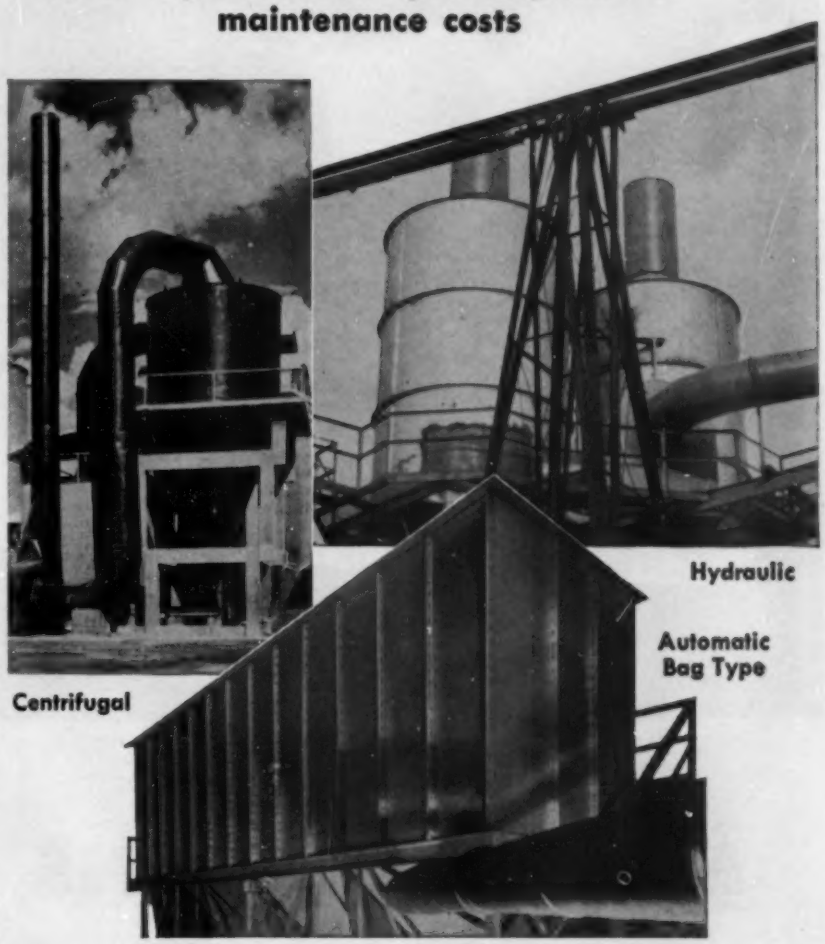
Research Engineers. (a) Research engineer or research metallurgist, Sc.D. or M.S. in mineral engineering or metallurgical engineering, to conduct research leading to better methods of mineral recovery. Two to 3 years experience as a research engineer is desirable. Must have demonstrated ability for initiating and directing experimental work in fields of mineral dressing or extractive metallurgy. (b) Research engineers, Ph.D. or Sc.D. in chemical engineering or extractive metallurgy for duties focused on the technology of extremely pure metal compounds and their subsequent reduction to metals. Will have responsibility for bench-scale to pilot-scale work on unit operations such as leaching, chlorination, distillation, melting, high temperature furnace work, solvent extraction, and ion exchange. Ability in preliminary design is desirable. Location, New York State. W1998.

Metallurgist, with at least a B.S. degree with major in metallurgy from a first class engineering college and with at least 2 years actual milling experience. Salary, $4800 to $6000 a year, Canadian currency. Location. Canada. W1986S.

Norblo

Dust and Fume Collection Systems

make outstanding records for high recovery with low operating and maintenance costs



Hydraulic

Automatic Bag Type

Centrifugal

These three important types of Norblo collecting systems, frequently used in certain combinations, bring you economical, dependable control as required in a wide range of industries. "Guaranteed Efficiency" is not an empty phrase at Norblo. We stand back of every installation that's used for the purpose and at the capacity for which we designed it. All component parts are made by Norblo, under controlled specifications.

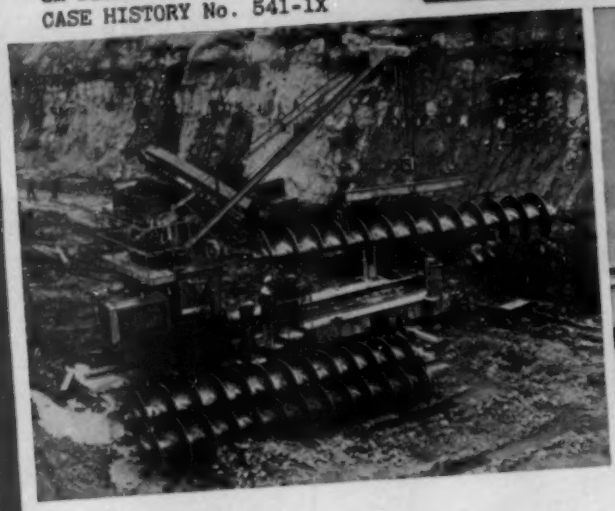
For more than 40 years Norblo has engineered and supplied installations of every size in the rock products, smelting, chemical, metal working, milling and processing fields. It pays you to get the facts about Norblo Dust and Fume Collecting Systems. Give us a description of your problems.

The Northern Blower Company

Engineered Dust Collection Systems for All Industries

6424 Barberton Ave. OLympic 1-1300 Cleveland 2, Ohio

GM DIESEL
CASE HISTORY No. 541-1X



OWNER: Peel Tree Mine, Clarksburg, W. Va.

INSTALLATION: GM "4-71" Diesel powers 42" McCarthy Coal Recovery Drill built by Salem Tool Company, Salem, Ohio.

PERFORMANCE: Mines up to 500 tons coal per day with 3-man crew. Works 9 to 11 hours per day drilling 170-foot holes 42" in diameter.

It Pays to STANDARDIZE on

... available in more than 250 models of equipment built by over 150 manufacturers

GM
GENERAL MOTORS
DIESEL POWER

MINES 500 TONS PER DAY
with GM Diesel Power

Quick-acting General Motors 2-cycle Diesel power speeds production and cuts costs in every kind of mining operation.

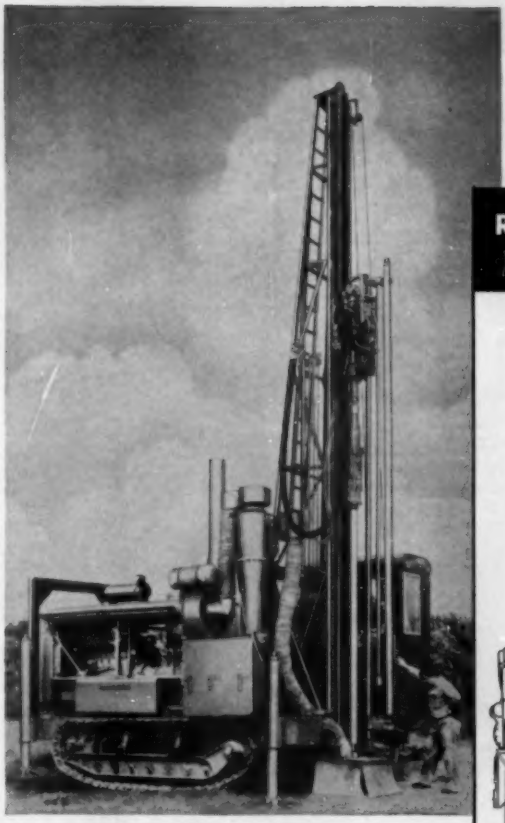
With power at every piston downstroke from 2-cycle operation, a GM Diesel accelerates faster, responds to controls quicker. It fits where other Diesels won't in many kinds of mining equipment because it packs more power into a smaller, lighter engine. Clean simple design makes maintenance easy, speeds servicing. And when parts are needed, GM Diesel distributors give quick delivery at low cost.

Call in your GM Diesel distributor for full details on GM Diesel power for your mine. And before you buy a Diesel, check parts costs, too. For example, GM Diesel cylinder liners cost up to 40% *less* than liners for other Diesels of comparable power. That's one reason why GM Diesels cost less to buy and less to maintain than other Diesel engines.

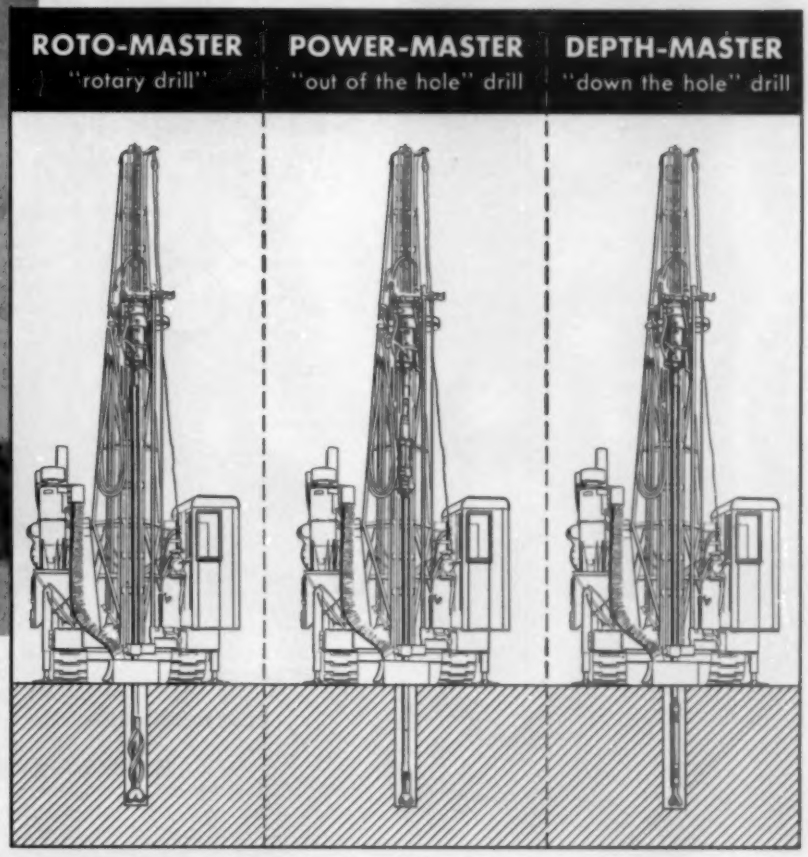
DETROIT DIESEL ENGINE DIVISION
GENERAL MOTORS • DETROIT 28, MICHIGAN
Single Engines... 30 to 300 H.P. Multiple Units... Up to 893 H.P.

new three-way DRILLMASTER

. . . the only self-contained, self-powered drilling rig that combines these *3* advanced drilling methods:



Ingersoll-Rand Drillmaster equipped with the Power-Master "out of the hole" drill. Independent rotation is provided by the Roto-Master rotary drill.



Here's a totally new *three-way* rock drilling machine that provides a range of hole sizes and drilling depths heretofore not available.

The ROTO-MASTER rotary drill is ideal for roller cone bit drilling of holes up to 6¼" in diam. in relatively soft ground.

The POWER-MASTER combination provides maximum efficiency for hard rock percussion drilling of holes up to 4¼" in diam. and up to 60 ft. in depth.

And the DEPTH-MASTER "down the hole" drill provides maximum drilling speed for percussion drilling of 6" diam. holes to any practical depth in quarrying and construction work. This unique drill actually goes down the hole with the bit, eliminating the waste of power normally required to overcome the inertia of long lengths of drill steel.

For the complete story on this revolutionary new three-way Drillmaster, send today for your copy of Bulletin No. 4164.

Ingersoll-Rand
11 BROADWAY, NEW YORK 4, N. Y.

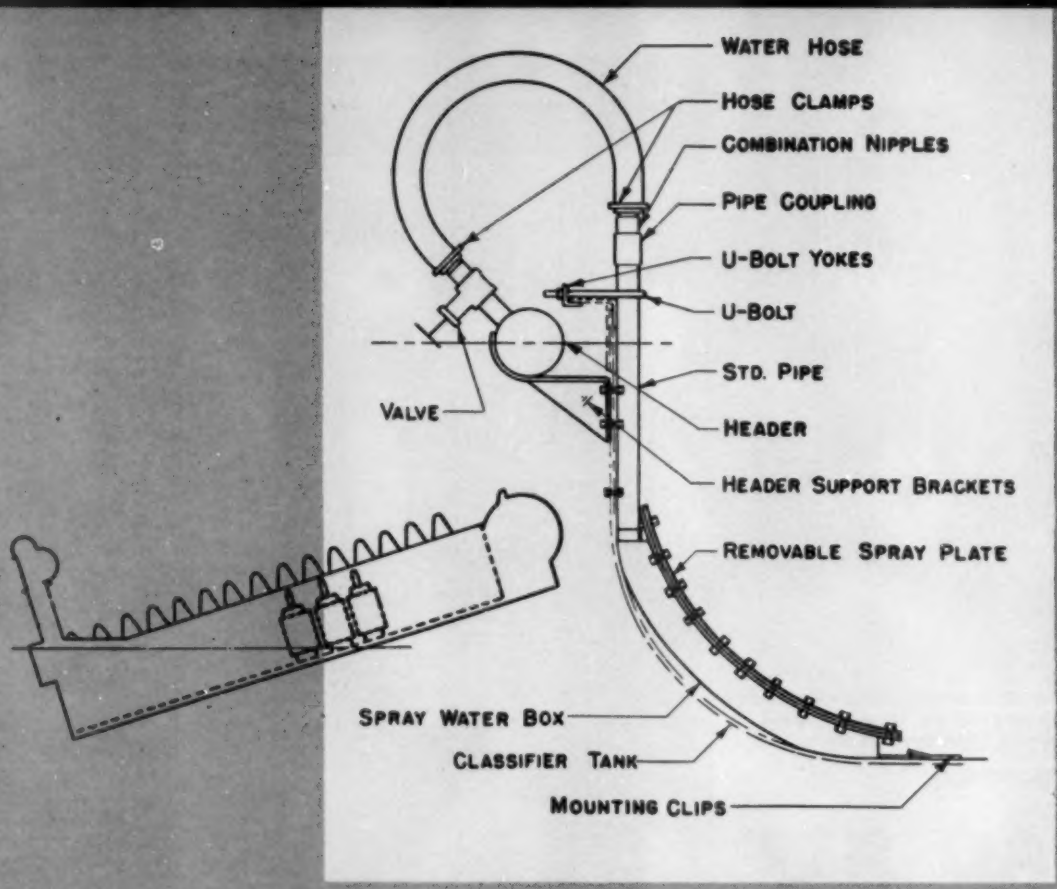
CARSET JACKBIT

5-223

ROCK DRILLS • COMPRESSORS • AIR TOOLS • TURBO BLOWERS • CONDENSERS • PUMPS • OIL & GAS ENGINES

spray water box attachment on AKINS Classifier

solves difficult sand-washing problems



The Akins Spray Water Box was developed by Colorado Iron Works Co. in 1937 and has proved to be particularly valuable in cases where adhesion of slime particles to sand is so persistent that a clean separation cannot be made by normal classification.

Spray Water Boxes, generally furnished in multiple assemblies, are easily and quickly bolted to the standard Akins Classifiers and are placed at the lower end of the drainage deck. The top spray plate is gasketed and bolted for quick, easy removal and replacement when spray holes are blinded.

COLORADO IRON WORKS CO.

1624 17th Street • Denver 2, Colorado

AKINS CLASSIFIERS • SKINNER ROASTERS • LOWDEN DRYERS

A SUBSIDIARY OF THE MINE & SMELTER SUPPLY CO.

Manufacturers News

News
Equipment
Catalogs

• FILL OUT THE CARD FOR MORE INFORMATION •

Shovel Crane

Schield Bantam Co., world's largest producer of truck-mounted power cranes and shovels, has announced a new self-propelled ⅜-yd shovel crane for general applications. Features are 6-ton lifting capacity and short turning radius of 19½ ft. **Circle No. 1.**

Assaying Counter

A scintillation counter suitable for prospecting and for assaying in the field, capable of functioning in

planes at speeds to 175 mph, and adapted to well logging is offered by *Chatham Electronics Div.*, Gera Corp. The sensitivity selector covers six ranges from 0.003 mr/hr to 1 mr/hr. **Circle No. 2.**

Tractor-Shovel Brakes

Four-wheel hydraulic brakes are now standard equipment on *Clark Eqpt. Co.'s* model 75A Michigan tractor-shovel. The 75A has a 1-cu

yd bucket, weighs 12,750 lb and is offered with 77-hp gasoline engine or 80-hp diesel power. **Circle No. 3.**

Quiet Screen

In the type V-52 Hum-mer electric screen vibrator there are no striking plates that contact, eliminating the principal source of noise. Despite quietness the *W. S. Tyler Co.* points out that the V-52 has ample power and effective intensity of vibration. **Circle No. 4**

Improved Hose

Flexaust hoses and Portovent retractable ducts are now available with a vinyl wearstrip to add protection and reduce external wear. The strip is bonded over the spiral wire reinforcement and at points where hose is most exposed to abrasion and damage. **Circle No. 5**

Dump Trucks

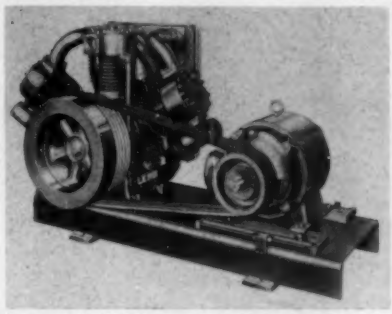
Mack Trucks Inc. has introduced two 8-yd capacity dump trucks for heavy duty service. Three transmission options and two engines are offered. **Circle No. 6**

Pulp Balance

A direct reading pulp balance from *Mine & Smelter Supply Co.* features easy reading scales for weight, specific gravity of liquid or pulp, percent solids, specific gravity of dry solids. No reference to charts or tables is needed. The Marcy pulp scale is so designed that dirt will not affect accuracy. **Circle No. 7**

Compressor Line

A new line of two-stage, air-cooled, electric motor driven compressors has been announced by *Le Roi Div.*, Westinghouse Air Brake Co. The 50,



75, and 100-hp stationary compressors have displacements of 260, 415, and 550 cfm at 125 psi operating pressure. **Circle No. 8**

Motor Wagon

A hydraulically operated bottom dump motor wagon with 22-yd heaped capacity has been added to

the line by *Allis-Chalmers*. A 280-hp diesel gives the 47,000-lb unit speed up to 20 mph. **Circle No. 9.**

Tough Screen Job?

The Deister Concentrator Co. model E FlexElex-equipped Leahy screens live up to their No-Blind trade name through dual action: differential motion keeps meshes clear of intermediate size wedging particles, while FlexElex keeps the screen wires warm and dry for uninterrupted production and freedom from blinding. **Circle No. 10**

Airborne Counter

The Radiac Co. has a scintillation counting system for helicopters or other light planes that is claimed to maintain efficiency at altitudes and

speeds in excess of those permitted by conventional counters. An automatic alarm signals the pilot whenever an anomaly is passed. Unit weighs 17 lb complete. **Circle No. 11**

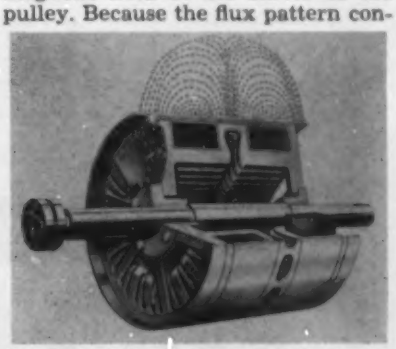
Reagent Feeder

Production is now underway on *Denver Eqpt. Co.'s* model 12A wet reagent feeder. Claimed to provide easier operation, lighter weight, laboratory accuracy, and greater vol-

ume, the unit has stainless steel float and other corrosion combatting features. **Circle No. 12**

Magnetic Pulley

Stearns Magnetic Inc. has announced a 2-coil electromagnetic pulley designed to produce a more effective flux pattern with deeper magnetic field at the center of the pulley. Because the flux pattern con-



forms to normal conveyor load conditions, it is stated that a smaller 2-coil pulley of this type will handle the same job as a larger 3-coil in many cases. The 2-coil pulley is available in variety of widths and diameters ranging from 12 to 60 in. **Circle No. 13**

Gardner-Denver CF93 Drifters, on Gardner-Denver Hydraulic Booms, at work in the Eucumbene-Tumut Tunnel

One of the many important tunnels driven by Gardner-Denver drills...exclusively!

Project: The Eucumbene-Tumut Tunnel Project for the Snowy Mountain Hydro Electric Authority of Australia.

Contractors: Kaiser-Walsh-Perini-Raymond.

Tunnel Data: The longest tunnel ever worked on a single heading—24 x 24 feet. A record performance of tunnel advancement of 402 ft. in 6 working days.

Gardner-Denver Equipment on the Job: 12 Gardner-Denver CF93 Drifters mounted on 4′ Slides. All machines mounted on Gardner-Denver Hydraulic Booms.

Find out why Gardner-Denver equipment has been first choice for more than 600,000 feet of major tunnel drilling throughout the world in the last five years alone.

GARDNER-DENVER

THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS FOR CONSTRUCTION, MINING, PETROLEUM AND GENERAL INDUSTRY

Gardner-Denver Company, Quincy, Illinois
In Canada: Gardner-Denver Company (Canada), Ltd., 14 Curity Ave., Toronto 16, Ontario

(21) U PROSPECTING LAWS: *Universal Atomics Corp.*, manufacturer and distributor of uranium detecting devices, has a survey of laws governing prospecting and mining for uranium on state owned lands. Covering 45 states, the survey gives a short summary of regulations and laws and tells where to write for further information.

(22) CENTRIFUGAL PUMPS: *Ingersoll-Rand's* 24-page bulletin 7093-E covers close-coupled Motorpumps from ¼ to 75-hp sizes for delivery of 5 to 2800 gpm. A visual and concise index shows the basic classifications of pumps and their specifications.

(23) INCREASED FOOTAGE: Easier operation, higher drilling speed, and sturdy dependability are essentials of Cleveland air legs and drills. Described in bulletin RD-30 from *Cleveland Rock Drill Div.*, four types have conventional or telescopic 3, 4, or 5-ft feeds. Some models take any 35, 45, or 55-lb drill.

(24) GEARS: *Falk Corp.* has a condensed treatise on selection and design of gearing for use on mills, kilns, and hoists. Clearly illustrated with drawings and photographs, report 6170 compares design and operating characteristics of various ring gears used to drive kilns and mills and indicates expected performance.

(25) SCINTILLATION COUNTER: Bulletin from *Mt. Sopris Instrument Corp.* announces the model SC188DA scintillation counter, designed for light plane or helicopter installations and easily carborne as well. Features include maximum ruggedness and reliability, advanced circuit design, and dual level discrimination against high and low energy radiation for limited spectral selection.

(26) DRILLING: Designed for quick, easy reference, the general catalog from *Hoffman Bros. Drilling Co.* covers a complete line of oriented diamond drill bits.

(27) BIN INDICATOR: *Bin-Dicator Co.* has a paddle-type bin level indicator for special installations. The Roto-Bin-Dicator unit is particularly adaptable to installations in bins under pressure or vacuum; bins, chutes or conveyors handling materials containing large lumps that tend to bridge over a diaphragm; and bins handling materials that tend to rat-hole and prevent operation of a diaphragm.

(28) FLOOR SPACE: *Zonolite Co.* booklet states that up to 1 sq ft of space may be gained around the perimeter of each floor by using thin wall sections of vermiculite. Construction time is at a minimum.

(29) COMMUNICATIONS: Users state that the M-S-A MinePhone system prevents lost time on haulageways and permits instant reporting of track conditions, roof falls, or any

other emergency with one message transmission. Four-page illustrated bulletin from *Mine Safety Appliances* describes the easily installed and operated frequency-modulated system and its component parts.

(30) DUST COLLECTION: *National Dust Collector Corp.* has a 12-page bulletin on the National Hydro-Filter that uses filtering principle to trap dust by impingement on glass spheres, entrapment on bubble surfaces, and containment within water droplets.

Free Literature

(31) COUNTERS: Bulletin from *Nuclear Measurements Corp.* includes specifications, construction features, and prices of four Geiger counters and three scintillation counters. All instruments feature book-type hinged construction, separate battery shelf, rubber shock mounted tubes, and soldered tube connections. They can be serviced quickly without tools.

(32) AIR POLLUTION: *Industrial Hygiene Foundation of America* has available a reprint of "The Estimation of Health Hazards from Air Pollution," by W. C. L. Hemeon. This 6-page article contains an hypothesis concerning identity of irritants in acute smog episodes.

(33) DIESELS: *Cummins Engine Co.* has a 40-page directory of original equipment manufacturers offering Cummins diesels as standard or optional power. Called the "Cummins Who's Who," the booklet lists the manufacturer's equipment and the corresponding diesel used for its power.

(34) EXCAVATORS: The 40-page bulletin from *Marion Power Shovel Co.* covers a complete line of excavating and materials handling machines, ranging from ¾-cu yd capacity to the 60-yd Marion 5760 coal stripper, the world's largest shovel. Bulletin 403-C features action photos of each basic machine type and condensed specifications.

(35) FILTERS: *Denver Eqpt. Co.* offers an analysis of any filtration problem by its Testing Div. in the 16-page buiietin FG-B1. Shown are Denver disk filters, drum filters, and laboratory filters used by metallurgical, chemical, coal, cement, water treatment, and other industries.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Jan. 15, 1956 — if mailed in U. S. or Canada.

Please send me { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	Students should write direct to manufacturer.						

Name_____ Title_____

Company_____

Street_____

City and Zone_____ State_____

(36) JOLTPROOF RECORDER: Bulletin DL-C 400 from *Texas Instruments Inc.* explains details of a unique clutch-actuated dual recording milliammeter. This ink-writing instrument features TI-developed high-torque magnetic fluid clutch meter movements and exclusive enclosed ink system that has made it ideal for use in plane, truck or boat.

(37) DRY FLUID DRIVE: The "fluid" in Flexidyne is heat-treated shot. *Dodge Mfg. Co.* has a 12-page bulletin explaining how Flexidyne starts, loads smoothly, protects against shocks and overloads and saves power.

(38) MACHINE REPAIR: Once costly brake drums, crankshafts, and axles were discarded when they became worn. "Metco News," published by *Metallizing Eng. Co.*, shows how metallizing now cuts maintenance costs 50 pct.

(39) SINTERING: The new *Dwight-Lloyd* sintering machine incorporates many engineering advances that improve sinter quality, reduce production costs, and establish standards for output and quality. Literature describes the Rowen windbox seal and other patented features.

(40) THREAD COMPOUND: *Jet Lube Inc.* has a leaflet on Thick-or-Thin sealing compound, a leakproof seal for threads, gaskets, and flanges. It is said to be highly resistant to all hydrocarbon products and gases, air, acids, alkalies, water, and chemicals.

(41) POOL WASHING SCREENS: Limestone, lead, zinc, coal are a few of the materials handled by *Allis-Chalmers'* pool washing screens. Bulletin uses diagrams to show how these screens provide efficient wet screening and effective media recovery while conserving water, increasing screening capacity, and minimizing blinding.

(42) CLAMSHELL BUCKETS: *Blaw-Knox Co.* has a 24-page catalog on two, three, and four line clamshell buckets for cement, chemical, and fertilizer industries. Classified tables of some 60 different sizes of buckets show weight and capacities.

(43) FADE-OUT PAPER: *Clearprint Paper Co.* has a catalog with sample sheets of a drawing and tracing paper printed with light blue cross-section rulings that completely disappear on direct print reproductions and blue prints.

(44) PIPELINE PROTECTION: *Minnesota Mining & Mfg. Co.* has a 16-page booklet on Scotch brand all-weather pipe wrap tapes, pipe primer, and a filament for attaching rock shields to buried pipe. Also shown are electrical insulation putty and electrical coating for use in protection of splices in anode ground bed installations.

(45) ACID HOSE: First issue of a new publication from *Du Pont's* Elastomers Div. for maintenance, operating, and design engineers briefly describes Hypalon. A length of acid hose constructed with a tube of Hypalon has outlasted regular acid hose by four times in chromic acid service and is still going strong.

(46) PAN-TYPE CONVEYORS: Bulletin 3255 from *Simplicity Eng. Co.* covers the series 32 pan-type conveyors available in two kinds of pan mountings and the vibration-free balanced pan-type conveyors. Action of the pan in second type is counterbalanced by weights at the ends of the rocker arms. Only a minimum of supporting structure is necessary.

(47) ROCKER SHOVEL: Bulletin L1009 from *Eimco Corp.* deals with the model 40 RockerShovel that employs the same rocker-arm shoveling action used in models 12B and 21. Equipped with a ½-cu yd bucket, machine loads at an average of 4 tons per min.

(48) LOG WASHER: *McLanahan & Stone Corp.* has developed the McLanahan Mudmaster for the removal of clay and other waste material from sand and gravel, crushed stone, ore, phosphate, and similar products. It is furnished with 10-in. sq box-section logs and is available in 25 and 30-ft lengths.

(49) FLOTATION: Bulletin from the Framco Products Div., *Frank M. Murphy & Associates Inc.* explains the Minerals Separation Airflow flotation machine, for years the work horse in Florida phosphate flotation plants. This machine, developed after extensive experimentation and testing by Minerals Separation North American Corp., one of the world's leading authorities on flotation, is now being built by Framco in a complete line of laboratory and commercial sizes.

(50) TRUCKING PROFITS: A weight-rate-profit chart has been formulated by *Alcoa* development engineers from operating records of aluminum track operators and owners. Yearly extra profits can be computed by using such known factors as weight saved with aluminum trucks or trailers, plus average rate for cargo carried and number of trips per year.

(51) ONE-SHOT VISCOMETER: *Gardner Laboratory Inc.* has information on a practical, disposable cup for making rapid, convenient, accurate, low cost viscosity determinations. The "One-Shot" viscometer consists of a disposable orifice cup fitted at the bottom with a metal orifice and a disposable receiver cup.

(52) SUPER-REFRACTORIES: Bulletin 317 from *Chas. Taylor Sons Co.* discusses properties and applications of TAYCOR super-refractories. TAYCOR is a corundum-base refractory recommended for furnaces where the refractory is subjected to abrasion and iron oxide attack at high temperature.

(53) VERTICAL DRILL: On-the-spot photographs in bulletin M-100 from *Salem Tool Co.* show the McCarthy vertical drill 106-24 in action. Made for strip mine operation, highway construction, soil engineering, and general construction, new drill handles augers 6 ft long up to 24 in. diam.

(54) EARTHMOVING: Six contractors moving all kinds of material on various jobs tell why they're operating at a profit in "DW21 Low Cost Earthmover" from *Caterpillar Tractor Co.* This unit gives them low cost per yard for the entire life of the machine.

FIRST CLASS
PERMIT No. 6433
Sec. 34.9 P.L.&R.
New York, N. Y.

BUSINESS REPLY CARD
NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

3c.—POSTAGE WILL BE PAID BY—

MINING ENGINEERING

29 WEST 39th STREET

NEW YORK 18, N. Y.

Cyanamid REAGENT NEWS

"ore-dressing ideas you can use"

Cuts Frother Costs Substantially by Replacing Cresylic Acid with AEROFROTH® 65 *Frother*

This copper property treating 220 tpd of an ore assaying 2.2% Cu had been using 0.5 lb. cresylic acid per ton of ore treated. Concentrates average 22%; tails average 0.2% copper. Mill tests showed that as little as 0.014 lb. of AEROFROTH 65 Frother could be used without any change in metallurgy.

The mill is now firmly established on AEROFROTH 65 Frother at the rate of 0.014 lb. per ton of ore treated. Daily frother consumption is now only 3.1 lb. of AEROFROTH 65 Frother instead of 110 lb. of cresylic acid. Other reagents used include 0.03 lb. AEROFLOAT® 238 Promoter; 0.03 lb. Sodium Ethyl Xanthate, and 8.0 lb. of lime per ton of ore treated.

This, we admit, is an unusual case. But it does indicate the substantial savings that may be made by substituting the proper AEROFROTH Frother for less efficient reagents. The Cyanamid Reagent family includes 5 AEROFROTH Frothers with a wide range of froth characteristics. These are described in Mineral Dressing Notes #20—"Cyanamid Reagents" which we will be pleased to send on request. A Cyanamid Field Engineer will be glad to work with you in selecting the frother best suited to your ore.

AMERICAN Cyanamid COMPANY

MINERAL DRESSING DEPARTMENT

30 ROCKEFELLER PLAZA, NEW YORK 20, N.Y.

Cable Address — Limenitro, New York

NORTH AMERICAN CYANAMID LIMITED
Royal Bank Bldg., Toronto 1, Ontario, Canada
CYANAMID DE MEXICO, S. A.,
Apartado No. 26012, Mexico 12, D. F., Mexico

CYANAMID PRODUCTS, LTD., Bush House,
Aldwych, London W. C. 2, England
SOUTH AFRICAN CYANAMID (PTY.) LTD.,
P. O. Box 7552, Johannesburg, Union of South Africa

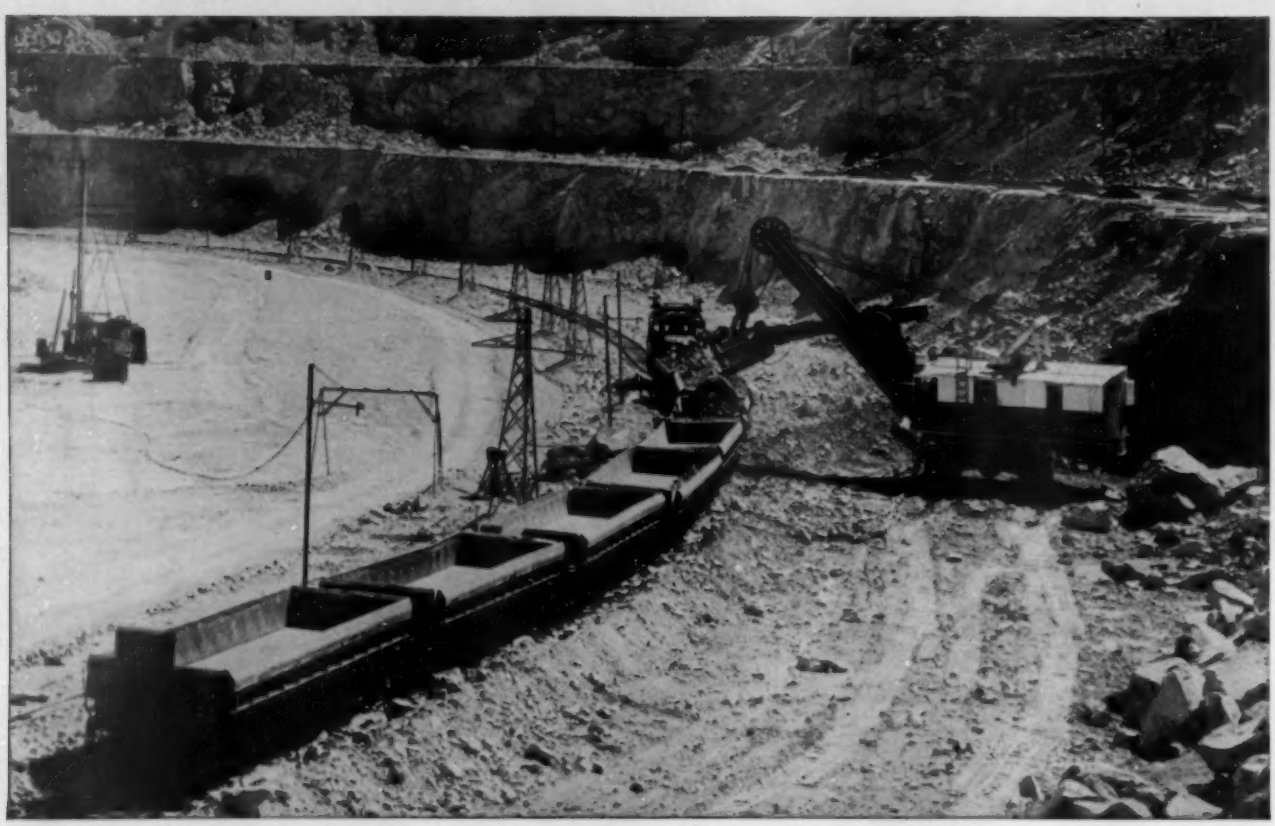
E. P. CADWELL, Casilla 12983,
Correo 11, Santiago, Chile
G. B. O'MALLEY, MALCOLM GLEN,
377 Little Collins St., Melbourne C.1, Australia

Printed in U. S. A.

Where parts must be

EXTRA TOUGH

specify AMSCO® MANGANESE STEEL



Digging! Crushing! Handling! Amsco manganese steel parts work up to 10 times longer under punishment . . . because manganese steel can easily absorb heavy impact and abrasion. Hard work toughens the metal . . . it work hardens to as high as 550 Brinell. The pounding, grating action of rock and ore only polishes manganese steel.

To get maximum life out of your equipment, specify Amsco manganese steel parts from the manufacturer.

DIGGING

dippers and parts
repointers
dragline buckets and parts
dragline chain
sheaves
pinions
crawler shoes

CRUSHING

concaves
mantles
jaw plates
mill liners
hammers

HANDLING

bulldozer blades
tractor rollers, idlers
sprockets, grouser bars
truck beds
grizzle parts
ore car wheels and liners
sheaves, gears, pinions

Amsco also produces other alloy steels with maximum wear resistance under particular conditions of service.

AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION
Chicago Heights, Ill.

Printed in U.S.A.

THERE IS A

TRUCO DIAMOND DRILL BIT

FOR MAXIMUM FOOTAGE

ON EVERY TYPE OF DRILL RIG

WHEEL TRUEING TOOL COMPANY

3200 W. Davison Avenue

Detroit • Michigan

WHEEL TRUEING TOOL CO. of CANADA, LTD.

575 Langlois Avenue

Windsor, Ont. • Canada

BOOKS

Centrifugal and Other Rotodynamic Pumps, by Herbert Addison, *Chapman & Hall Ltd.*, London, approximately $7.00, 2d ed., 530 pp., 1955.—The entire range of centrifugal, screw, and propeller pumps is covered in four sections dealing with principles, design and construction, performance, and installation. In the revision, minor changes have been made in accordance with advances in practice, and the bibliography has been brought up to date. Forty-eight worked examples of pump and pumping-plant problems are appended.

Tungsten, by K. C. Li and Chung Yu Wang, ACS Monograph No. 130, *Reinhold Publishing Corp.*, $14.00, 475 pp., 3rd edition, 1955.—Mr. Li is chairman and Mr. Wang is director of research, Wah Chang Corp. Their authoritative and up-to-date book covers in detail every aspect of the history, geology, ore dressing, metallurgy, chemistry, analysis, industrial applications, substitutes, and economics of tungsten.

Nuclear and Radiochemistry, by Gerhart Friedlander and Joseph W. Kennedy, *John Wiley & Sons Inc.*, $7.50, 468 pp., 1955.—Written from the chemist's viewpoint, this revised version of *Introduction to Radiochemistry* contains up-to-date material on atomic nucleii and radiation detection and measurement. Two new chapters have been added on nuclear energy and cosmic problems. The first deals with nuclear reactors and military applications and the second goes into energy production in stars, cosmic rays, and cosmic and geological dating methods.

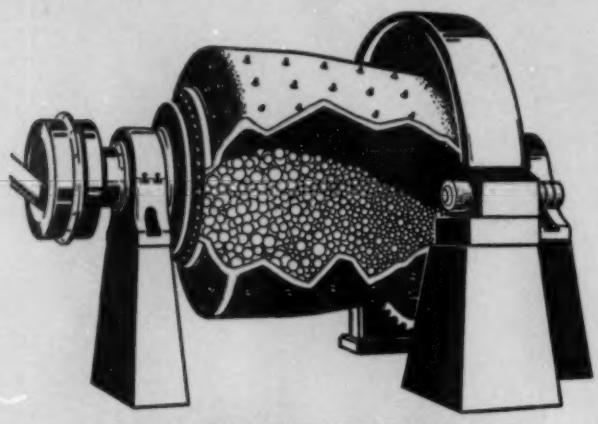
MEMBERS, ORDER YOUR BOOKS THROUGH AIME—Address Irene K. Sharp, Book Department. Ten pct discount given whenever possible.

Chemical Engineering Cost Estimation, by Robert S. Aries and Robert D. Newton, *McGraw-Hill Book Co. Inc.*, $6.00, 255 pp., 1955.—An outline of the principles of cost estimating and evaluation together with cost estimating data. Contents include: capital investment, physical plant cost, effect of variable conditions on costs and profits, economic evaluation, nomenclature, and sample problems.

Engineering Metallurgy, by L. F. Mondolfo and Otto Zmeskal, *McGraw-Hill Book Co. Inc.*, $7.50, 397 pp., 1955.—Mr. Mondolfo is professor of metallurgical engineering, Illinois Institute of Technology, and Mr. Zmeskal is research professor, mechanical engineering dept., University of Florida. Their book is a modern college text for the teaching of metallurgy to engineering students whose primary interest does not lie in the metallurgy field. Emphasis is on the theoretical reasons behind operations and the basic theory of metallurgy is stressed as an introduction to practical applications. Unity of concept is the underlying theme, as opposed to compartmentalization of the behavior of individual metals.

Practical Plant Layout, by Richard Muther, *McGraw-Hill Book Co. Inc.*, $12.00, 363 pp., 1955.—This practical treatment of layout techniques and procedures discusses the factors influencing layout materials, machinery, manpower, etc. Step-by-step directions for planning the arrangement of equipment and work areas are given. Basic features of types of layouts and their relation to production are dealt with in introductory chapters, and the role of management is discussed in the final chapter. Detailed examples, case illustrations, and extensive appendices of useful data are included.

Principles of Industrial Waste Treatment, by C. Fred Gurnham, *John Wiley & Sons Inc.*, $9.50, 399 pp., 1955.—The greater part of this book for practicing engineers and students is a discussion of operations and processes used to treat wastes before discharging them into natural streams or municipal sewers: sedimentation, filtration, heat transfer operations, and various chemical and biological treatments. Pollutional effects and criteria for evaluating pollution are also discussed.



TRICONE MILLS

Highest grinding efficiency and *lowest* ball and lining wear are common to mills with a correctly segregated ball charge.

The *Hardinge Tricone Mill* is the only mill providing these essentials to low cost operation *without* the use of special linings or internal devices, which are subject to wear and are effective through only a part of their wearing life.

Complete specifications upon request. Bulletin AH-414-2.

Four 11′ diameter Hardinge Tricone Mills at a Canadian Concentrating Plant.

HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

New York • Toronto • Chicago • Hibbing • Houston • Salt Lake City • San Francisco

MAXIMUM RECOVERY WITH HERCULES FLOTATION AGENTS

In the flotation of phosphate, feldspar, and mica, Hercules' Rosin Amine D Acetate has demonstrated its value as a highly efficient collector.

A cationic surface-active material, Rosin Amine D Acetate serves as an excellent collector for silica and silicate minerals as well as being useful in the beneficiation of nonmetallic ores.

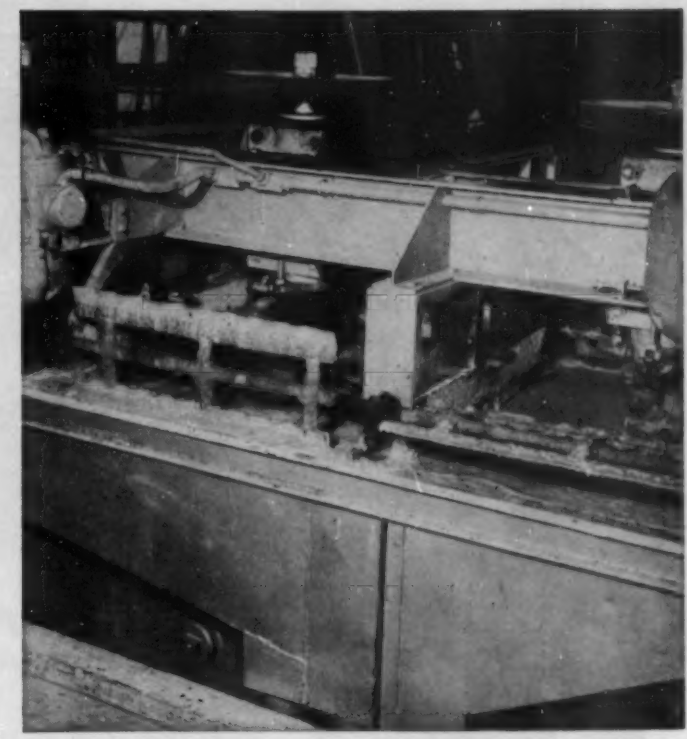
A new addition to the Hercules family of flotation agents is Terposol® 50, a synthetic frother developed for general application in the flotation field. Now available in pilot plant quantities, Terposol 50 has displayed excellent frothing properties in the flotation of both sulfide and nonsulfide minerals.

For technical information on these and other Hercules' flotation agents, write:

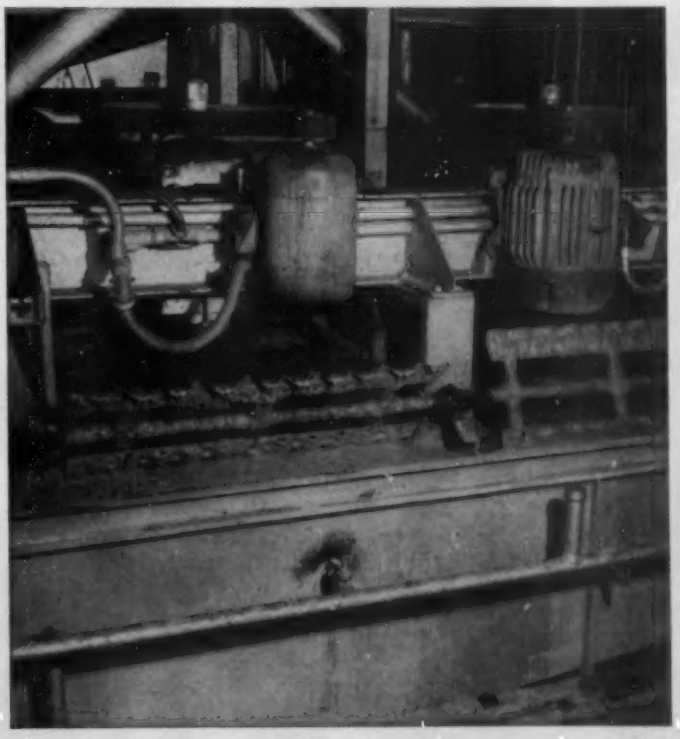
Naval Stores Department
HERCULES POWDER COMPANY
INCORPORATED
955 King St., Wilmington 99, Del.

HERCULES
FLOTATION AGENTS

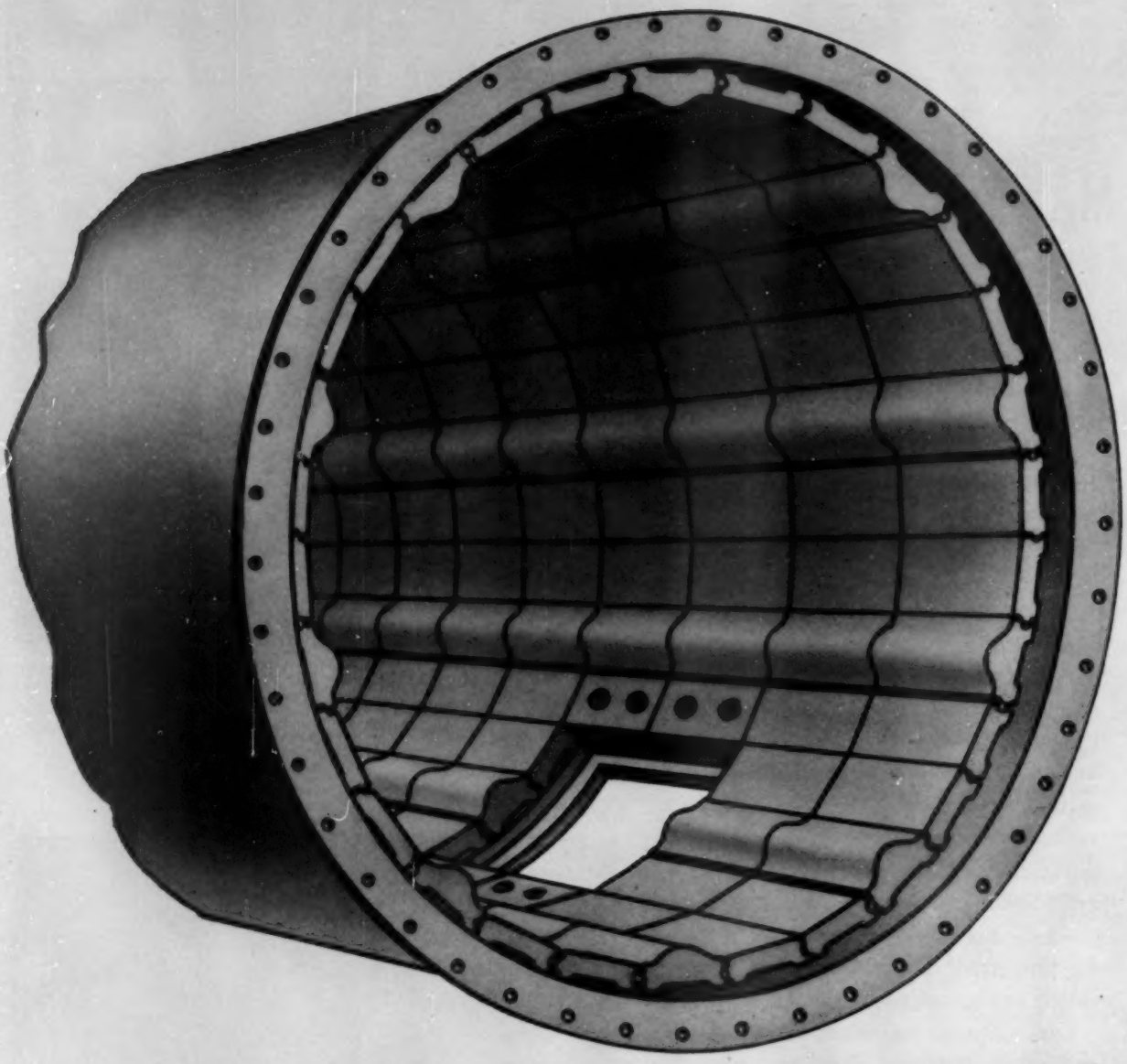
NM66-1



INITIAL STEP—Phosphate recovery begins in this large plant with a fatty acid flotation step whereby phosphate is separated from the sand.



SECOND STEP—Final purification follows during which most of the sand remaining in the initial phosphate concentrate is floated with rosin amine.



Babcock & Wilcox introduces a new type ball mill liner of Ni-Hard

This drawing illustrates a type of mill operated by a large midwestern Portland cement company, that uses 1¾ in. make-up balls. These liners are readily adaptable for mills used in the processing of metallic ores.

It shows the new type Elverite C (Ni-Hard®) liners, developed and produced by Babcock & Wilcox, Barberton, Ohio.

The reported condition of these liners after 14 months' service indicates a 4-year life expectancy.

B&W is an authorized producer of Ni-Hard castings, and supplies these versatile liners in a combination of plain and wave segments to satisfy individual grinding requirements in mills of varying design.

It will pay you to learn what Ni-Hard can do for you. Instead of outmoded liner material, use Ni-Hard . . . because it brings you *abrasion resistance at lowest ultimate cost.*

INCO TRADE MARK **THE INTERNATIONAL NICKEL COMPANY, INC.** 67 Wall Street New York 5, N.Y.

Spotlight on Rare Metals

AEC wants 2 million lb of zirconium over five-year period or 1.2 million lb in three years (together with associated hafnium) in addition to 200,000 lb of zirconium and 4,000 lb of hafnium now supplied yearly by Carborundum Metals Co. . . . O. A. Beath of the University of Wyoming reports discovery of a selenium deposit near Baggs, Wyo. Metal is now scarce at $13 per lb. . . . Onego Corp. claims major thorium find—4 million tons of monazite sands—in the Sangre de Cristo mountains about 75 miles from Santa Fe, N. M. . . . Interest is high on columbium-tantalum ores, although Government stockpiling is largely complete. Fansteel Metallurgical Corp. is continuing to purchase tantalum ore concentrates containing at least 30 pct Ta_2O_5, but ores of lower grade will be considered.

Copper

Fabricators in Connecticut made a fast recovery from flood damage as copper prices stabilized at 43¢ from primary producers—50¢ from custom smelters. London market eased. Inventory building was expected to hold price up for some time.

Industrial Minerals

Pacific Coast Borax Co. is starting manufacture of elemental boron with purity from 90 to 97 pct on pilot plant scale. Prices are $10 to $15 per lb. . . . Spar-Mica Corp. Ltd. raised $2 million for development of its Quebec feldspar properties and for shipping facilities. . . . International Minerals & Chemical Corp. will soon complete commercial feldspar beneficiation plant using company's electrostatic process.

Iron Ore Flows to Mills

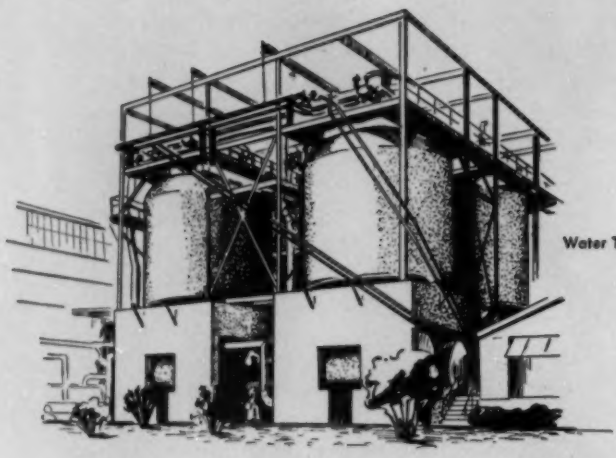
With steel mills producing 75.8 million tons for the first eight months, just under the 1953 record, Great Lakes carriers scheduled a 78 to 80 million ton ore season. Foreign iron ore imports were forecast at 20 million tons.

Uranium Developments

Consolidated Denison Mines Ltd. will have world's largest uranium mill operating early in 1957. Millsite is company's mine in Canada's Blind River area and a $182 million contract has been signed with Canadian Government. A five-compartment 1700-ft shaft and a seven-compartment 250-ft shaft are now being sunk. . . . Western Knapp Engineering Div. expects to complete preliminary facilities and buildings this year for Mines Development Inc., uranium mill at Edgemont, S. D. . . . Widespread aerial prospecting for uranium was under way this season in Alaska.

Mining Companies in the Headlines

Ventures Ltd. has chosen Robert B. Anderson as new president. Mr. Anderson, recently Deputy Secretary of Defense and a former Secretary of the Navy, takes the place of Thayer Lindsley. Mr. Lindsley is expected to become chairman of the board. . . . Harvey Machine Co. gets Government go-ahead for $65 million, 108 million lb capacity aluminum plant at The Dalles, Ore. . . . Bunker Hill & Sullivan Mining & Concentrating Co. plans to acquire the 50 pct interest in Sullivan Mining Co. now held by Hecla Mining Co. Bunker Hill will also acquire 36 pct interest in Pend Oreille Mines & Metals, while Hecla will gain 17 pct of Bunker Hill's common stock. . . . National Lead Co. will have 80 pct of a new Australian company. The subsidiary, Mineral Deposits Pty. Ltd., is in rutile and ilmenite field.



Water Treating Plant

Crude Sulphur

for Industrial Use

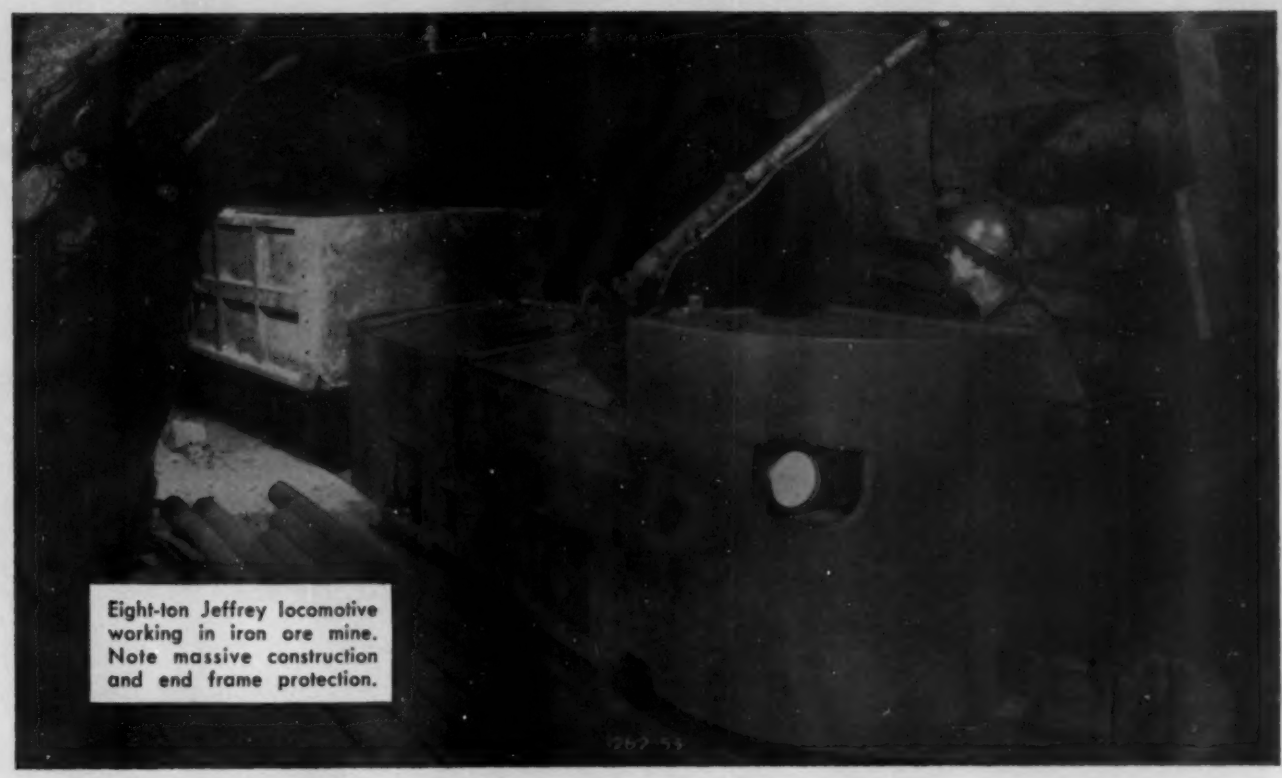
from the properties of

Texas Gulf Sulphur Co.

75 East 45th Street • New York 17, N. Y.

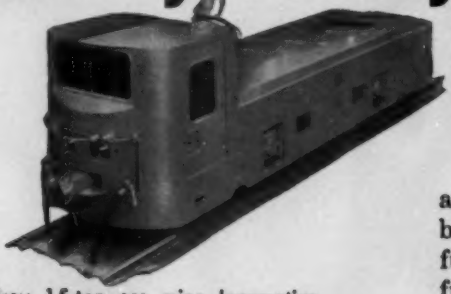
Producing Units

- **NEWGULF, TEXAS**
- **MOSS BLUFF, TEXAS**
- **SPINDLETOP, TEXAS**
- **WORLAND, WYOMING**



Eight-ton Jeffrey locomotive working in iron ore mine. Note massive construction and end frame protection.

Jeffrey Trolley Locomotives improve metal mine haulage



Jeffrey 15-ton ore mine locomotive. Enclosed cab offers weather protection for motorman on outside portion of haul and protection from roof falls on inside.

Six-ton Jeffrey ore mine locomotive. Rounded, welded end frames and smooth side frames with no projecting parts are desirable safety features.

Protection against "down time" and accidents to personnel are just two of the ways Jeffrey power-packed trolley locomotives benefit metal mine operations. For example, electrical equipment is fully shielded from water dripping from the roof or splashing up from the track. Gable-type covers with center channel provide drainage. Rounded end frames, the same height as side frames, protect motorman and trip rider.

Features like these can be built into any of Jeffrey's complete line of four-wheel metal mine locomotives in 4, 6, 8, 11, 15 and 20-ton sizes, and the eight-wheel 27-ton unit. The line spans the narrow gauge field—24", 30" and 36".

Jeffrey trolley locomotives are sturdy, streamlined, easy to operate and repair. Throughout the mining world they haul high tonnage at low cost and are well known for reliability and long-term service.

THE JEFFREY MANUFACTURING CO.

ESTABLISHED 1877

Columbus 16, Ohio

sales offices and distributors in principal cities

PLANTS IN CANADA, ENGLAND, SOUTH AFRICA

IF IT'S MINED, PROCESSED OR MOVED

. . .IT'S A JOB FOR JEFFREY!

CF&I ROCK BOLTS

make mine roofs and walls *SELF-SUPPORTING*

Conventional mine timbering is as old-fashioned as it is cumbersome, dangerous and expensive.

With CF&I Rock Bolts, there's no need for bulky timbers that require added transportation and installation, that restrict the efficient operation of machinery and limit miners' output. CF&I Rock Bolts are simply anchored in mine roofs and walls, and give secure support.

CF&I Rock Bolts offer these advantages:

- **Reduce danger of roof falls due to blast effect**
- **Provide valuable additional working space**
- **Afford better ventilation**
- **Are less bulky to store and haul**
- **Low-cost installation**

SLOT & WEDGE TYPE

EXPANSION SHELL TYPE

CF&I Rock Bolts are available in slot and wedge type and expansion shell type with Pattin shell.

Learn how CF&I Rock Bolts can improve your own operations. Write today for descriptive information.

3185

CF&I ROCK BOLTS

CF&I STEEL PRODUCTS FOR THE MINING INDUSTRY

Grinding Balls • Grinding Rods • Wickwire Rope • Mine Rails and Accessories • Cal-Wic Industrial Screens

Braun Consulting Reports

Consulting Engineering

If you are contemplating investment in new processing facilities, or are seeking better returns from your existing plant, our consulting experience may be helpful to you.

The Company's consulting activities are largely in the field of the petroleum, chemical and ore-processing industries. Our experience includes market research, economic studies, process comparison, site-selection and maintenance surveys.

Braun
engineers

C F BRAUN & CO *Alhambra California*

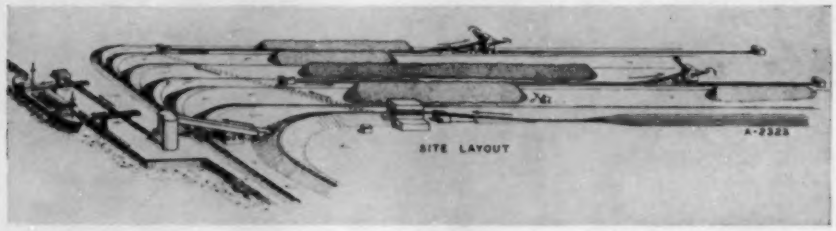
New York Chicago Tulsa Houston San Francisco · C F Braun & Co of Canada Ltd · Braun Transworld Corporation

PROJECT ENGINEERING · PROCESS · DESIGN · FABRICATION · CONSTRUCTION · CONSULTING · APPLIED RESEARCH

CONVEYING LABRADOR IRON ORE-- 10,000,000 TONS ANNUAL CAPACITY

IRON ORE COMPANY OF CANADA— THE PORT OF SEVEN ISLANDS, QUEBEC

The S-A Conveying System provides for stockpiling or loading at dockside. Here, the traveling stacker is building a stockpile at the rate of 3750 net tons per hour. Conveyor booms stockpile to either side.



After crushing S-A Amsco Feeders carry the ore to these 60" belt conveyors which feed the ship loading boom belts.

At the docks, twin boom belts on traveling bridges with a combined capacity of 10,000 net tons per hour can load even the largest ocean-going ore ships in about 5 hours. Booms pivot up or down to compensate for tide or ship conditions.

• From the Port of Seven Islands, Quebec, 10,000,000 tons a year of Labrador iron ore will pour into America's industries. This feat of production must be done in the 150 to 160 days of good weather, during which ships can be loaded. An S-A Conveying System, handling an average of 70,000 tons of ore every day for loading and stockpiling, is helping make the job possible.

You may never need a conveying system as large or complex as the one at the Port of Seven Islands. But, whatever your bulk handling need, S-A engineers can show you an economical answer. Write for a free survey. No obligation, of course.

STEPHENS-ADAMSON MFG. CO.

37 Ridgeway Avenue, Aurora, Illinois

Los Angeles, Calif. • Belleville, Ontario

Engineering Division	Specialists in the design and manufacture of all types of bulk materials conveying systems.
Standard Products Division	A complete line of conveyor accessories including centrifugal loaders—car pullers—bin level controls—etc.
Sealmaster Division	A complete line of industrial ball bearing units available in both standard and special housings.

50 mm dia. rubber block cyclones at left . . . double 30 mm dia. block at right.

Multiple Molded Rubber Block Cyclones Make Sharp Separations in 10 - 20 Micron Range . . .

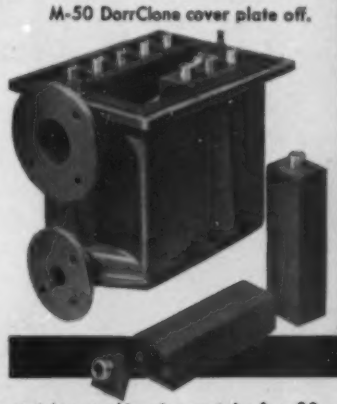
Latest advance in wet cyclone design is the Type M DorrClone . . . developed for size separations in the 10 to 20 micron range. Designated as M-30 and M-50, this new design is now available with twenty 30 mm dia. rubber block cyclones or ten 50 mm cyclones in a common housing. Housings may be either cast stainless steel or bronze construction. When cover plate is bolted in place, each block is under compression to form a tight seal between feed, overflow and underflow chambers.

As with all cyclones, capacity and mesh of separation in the M DorrClone varies with the diameter of the individual units, operating pressure, feed solids concentration and specific gravity of the solids. On a slurry with a solids specific gravity of 2.7, the M-30 separates at 8-10 microns and the M-50 at 15-20 microns. As to capacity, the M-30 handles approximately 70 gpm at 20 psi, 100 gpm at 40 psi and 125 gpm at 60 psi. At these pressures the M-50 handles approximately 100 gpm, 140 gpm and 170 gpm. Top operating pressure for both is 125 psi.

For more information on this newest classification tool write for a copy of Bulletin No. 2504. Dorr-Oliver Inc., Stamford, Connecticut.

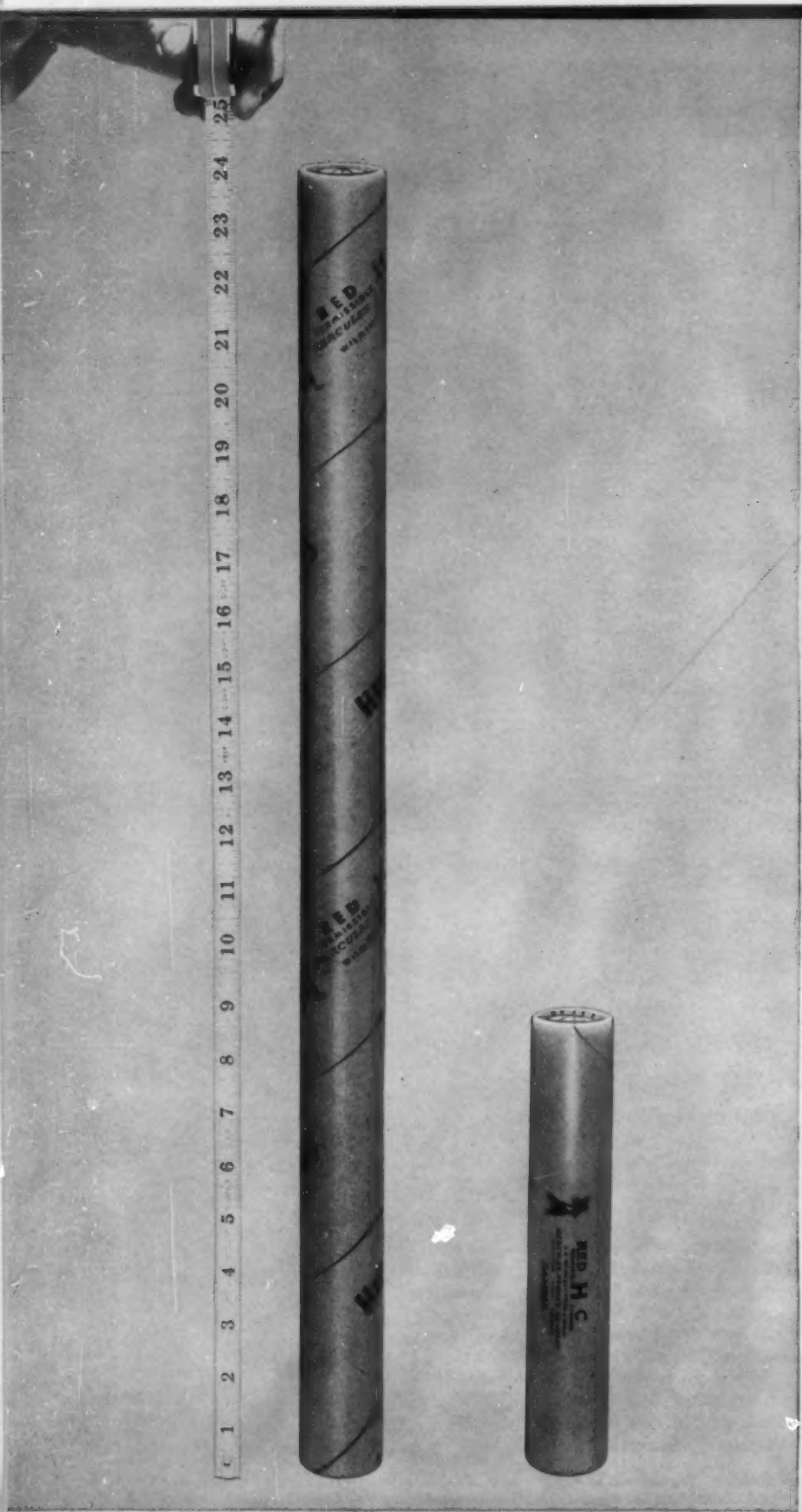
M-30 DorrClone completely assembled.

M-50 DorrClone cover plate off.



Lab units also available . . . for test units or very low flows. Fabricate stainless steel housing contains four 30 mm units or two 50 mm units. Separations are the same with equal diameter cyclones. Write for quotation.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.



THE LONG AND THE SHORT OF IT . . . Here is a new Hercules "King-Size" permissible cartridge—24 inches in length—shown alongside the same grade in the conventional 8-inch size.

NOW... "KING-SIZE" PERMISSIBLES

Hercules permissible powders packed in "King-Size" cartridges are now available for use in coal mines. Field tests of these new "King-Size" cartridges show that they have many advantages, some of which are:

- **A continuous column of permissible powder in bore holes minimizes misfires and reduces the hazard of unshot powder in the coal.**
- **Predetermined cartridge weights effect economies in the powder consumption.**
- **Uniformity in loading produces uniform breakage.**

Hercules "King-Size" cartridges are supplied in most permissible grades, in lengths from 12 to 24 inches and in diameters of 1¼ to 2 inches.

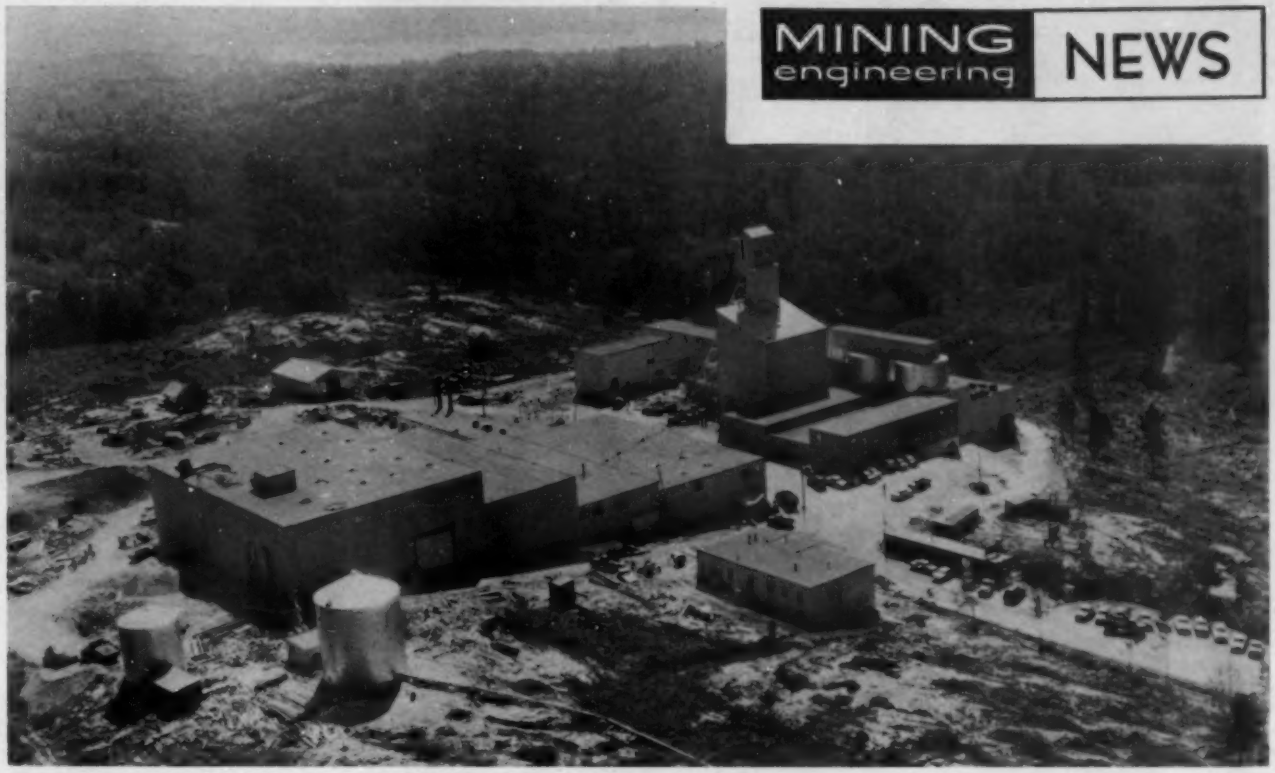
Our representatives are ready to discuss your explosives needs and to give more information on how the new "King-Size" cartridges can do more work for you at lower cost.

HERCULES POWDER COMPANY
INCORPORATED
Explosives Department, 955 King Street, Wilmington 9, Delaware

Birmingham, Ala.; Chicago, Ill.; Duluth, Minn.; Hazleton, Pa.; Joplin, Mo.; Los Angeles, Calif.; New York, N. Y.; Pittsburgh, Pa.; Salt Lake City, Utah; San Francisco, Calif.

HERCULES

XR55-8



Pronto Uranium Goes Into Production

Blind River's First Mill is 4 Months Ahead of Schedule

Canada's first large privately owned uranium plant is now in production in the Blind River district. Pronto Uranium Mines Ltd. is off to a running start with mill operation four months ahead of Jan. 1, 1956 contract completion date.

Speaking of the mill, Franc. R. Joubin, the geologist whose theories led to the Algoma camp, said: "Pronto has broken, for a mine of this size, all Canadian speed records for elapsed time from the first drilling in April 1953 to the start of its mill . . ."

Surface structures at Pronto extend over 20 acres, and the company has invested about $7 million in overall plant and equipment. Underground development includes a 550-ft, three-compartment production shaft equipped to handle 2500 tpd. Five mining levels have been laid out.

Pronto's operations are managed by Technical Mines Consultants Ltd., Toronto, and the firm has a contract with a Crown company for sale of $55 million worth of uranium concentrates over the next five years.

Aerial view of Pronto Plant by Photographic Survey Corp. Ltd. shows, left to right, the sulphuric acid and water tanks, with mill proper at left center. Analytical laboratories are at right center foreground. General offices, hoist house, fine ore bins, and crusher and grinding section are in the group of buildings about the headframe. Lake Huron is in the distance.

THEN AND NOW: Forty-five years ago in 1910 the first long-boom, full-revolving American stripping shovel was built and shipped to a Kansas coal field by a firm which in later years became part of Bucyrus-Erie Co. of South Milwaukee, Wis. With a 55-ft boom and 40-ft handle, the steam-powered machine swung a 2½-yd dipper over a 31-ft reach. It was the forerunner of the monster crawler-mounted coal strippers of today such as the Bucyrus-Erie 1050-B electric shovel shown at right. Comparative statistics on the new machine are: 113-ft boom, 64-ft handle, 45-yd dipper, and a dumping radius of 114 ft at 74-ft heights. This year the firm is celebrating its 75th anniversary as a manufacturer of excavating equipment.

Consolidated Coppermines

Expands Kimberly, Nev., Open Pit Operations

Company Will Use Own Earthmoving Equipment

A major expansion of open pit mining was inaugurated this year by Consolidated Coppermines Corp. at its Kimberly, Nev., operations. The expansion program, which will insure continued operations in company pits for at least 10 to 12 years, was coupled with the firm's decision to purchase its own earthmoving equipment. Prior to this year Consolidated has contracted with Isbell Construction Co. of Reno to move waste material from pits and haul ore to the railroad. From the rail point ore goes to the Kennecott concentrator and smelter at McGill, Nev.

An intensive churn drilling program was begun Mar. 25, 1955 and by July 5 actual stripping started. Company officials selected the 22-ton Euclid rear-dump truck for actual haulage and now have 14 in operation. In addition three P&H shovels were purchased for mining and loading.

The development will bring added employment to the region and assures continued operation for many years. Consolidated officials note that when the firm began open pit mining in 1950 there were about 50 men on the payroll. At that time ore excavation was under Isbell Construction. There are now 160 men working for Consolidated and employment will probably reach 200.

Start of Consolidated's new pit marks renewed life for historic mining area. Morris and Brooks claims were long operated by both underground and surface mining methods. Ore is hauled by railroad to Kennecott's McGill mill and smelter for treatment. Shown above is one of the three new P&H shovels for mining and loading.

An Historic Area

In 1867 a man known as Indian John took a party of prospectors to the desolate area and displayed samples he had found. Gold was then the major interest with silver a close second. Hamilton, some 30 miles west of Ely, was a roaring silver camp. Then in the early 1900's gold took a secondary role when low grade copper ore was found.

In the early days more than 1000 mining claims were filed in the area. Towns grew in the midst of rocky hills and on sagebrush-covered flats. Only a few of the towns remain, such as Ely, Ruth, and Kimberly. Recently mining expansion caused the entire town of Ruth to be moved as houses, businesses, garages, and utilities were shifted to form the town of New Ruth. The old town has now been undermined, as operations of Kennecott's Copper Flat pit bit into the underlying ore.

The Beginnings of Consolidated Coppermines Corp.

The whole area was first opened to large-scale mining in 1906 when Mark Requa guided construction of the Nevada Northern RR from Ely north to connect with the Southern Pacific. Nevada Consolidated Copper Co. started ore production in 1907 and began milling and smelting in 1908 using the methods originated by D. C. Jackling.

The Morris and Brooks claims areas were first developed about

Pictured are the 14 new Euclid trucks purchased by Consolidated Coppermines from Foulger Eqpt. Co. of Salt Lake City. These 22-ton rear-dump trucks and other new equipment enabled firm to start mining and hauling its own ore from the pits to the railroad terminal.

1910. Mining in the high grade area on the two claims by top slicing continued until World War I, when block caving was adopted. In 1926 mining operations were started on an increased basis and about the same time the Emma Nevada was opened using block caving adapted to the particular problems of the region. Production from the Morris and Brooks was then about 6000 tpd. In 1938 connection of these two operations by underground drifts was begun, a task completed in 1940. By then daily rated capacity of both operations was 9000 tpd.

These operations continued until 1949 when work was stopped because of economic considerations. It was not until a year later that life returned to the copper pits when the Isbell Construction Co. was awarded a contract for open pit operation in the vicinity of the Morris and Brooks area. Work has continued since then and Morris pit, already deep, is said to be only in the early stage of its development.

Tripp Copper Pit

Consolidated will be moving 7000 tpd of ore seven days a week as well as stripping 20,000 tpd of rock and dirt. After the initial period the stripping ratio will drop somewhat, the engineers say. And company engineers estimate that 50 million tons of ore and waste will eventually be moved to create the Tripp copper pit, which will cover an area 1700x 3200 ft when fully developed.

A new copper mine in White Pine County, Nev., is being created by Consolidated Coppermines Co. at Kimberly. Scene is at east end of the Tripp excavation.

It was exploration that gave the company the incentive to begin its own hauling and mining. Additional ore reserves in the vicinity of the Brooks and Morris pits justified purchasing the necessary equipment.

Maintenance and servicing of the fleet of heavy equipment created new problems. These fell in the province of Tom Gilmour, master mechanic, who worked out the special procedures to meet company requirements with the aid of Foulger Eqpt. Co. of Salt Lake City.

During the summer new garage installations were built consisting principally of a six-bay main service unit. Added facilities will care for motor and transmission repairs. A parts dept., tire service dept., a large storage building, a welding shop, and a wash rack are also provided.

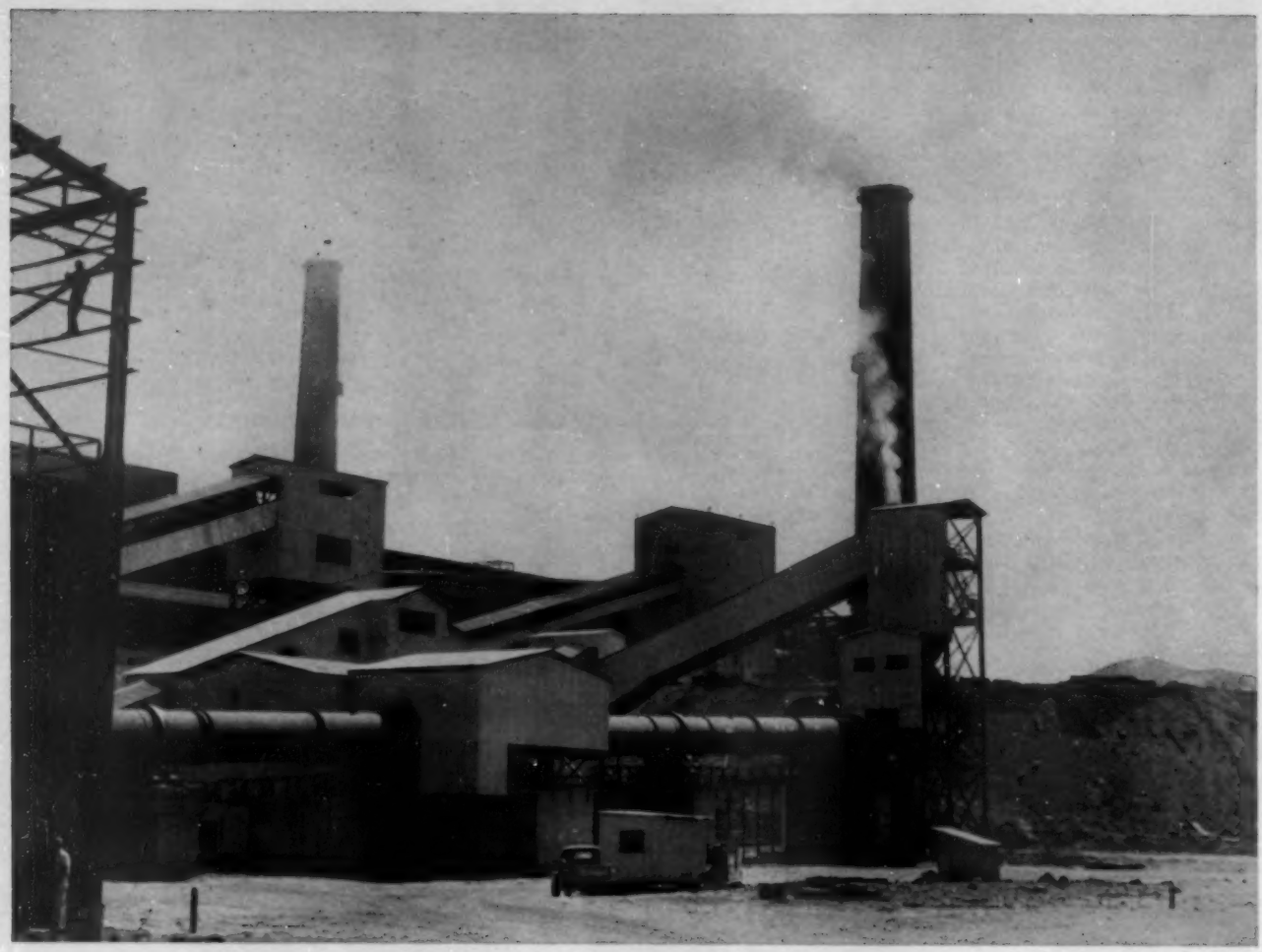
Present Staff

The present staff of key personnel under A. J. O'Connor, Consolidated's vice president and general manager, are: J. Frank Sharp, superintendent of pit operations; John Eaby, chief clerk; W. J. Latvala, superintendent of pit operations; Harry Brindle, chief mining engineer; Thomas Gilmour, master mechanic; M. Shields, chief electrician; and J. M. Forbes, chief geologist.

Mile-long Conveyor Belt System Replaces Aerial Tramway at Cement Property

ABOVE: Mile-long conveyor system at Alpha Portland Cement Co., Catskill, N. Y. Plant and Hudson River are in background. Conveyor, which transports limestone at 300 tph from screening station to storage area, replaced aerial tramway seen at right.

RIGHT: Closeup of conveyor at Alpha Portland Cement also shows the aerial tramway which was replaced. System crosses the West Shore Ry and U.S. Highway 9-W on special overhead galleries. Hewitt-Robins Inc. designed, built, and installed complete system.



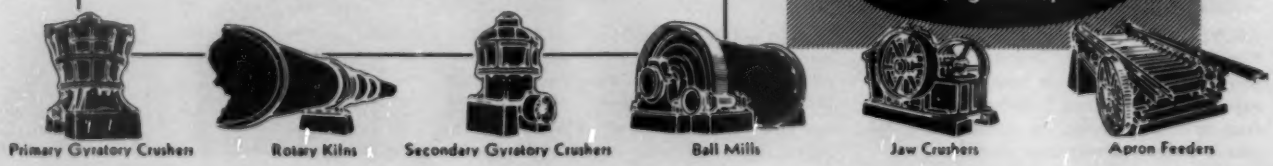
6 Miles of Traylor Rotary Kilns Prove Traylor Design Pays Off in the Long Run

In the past 14 years, Traylor has built almost 1 Rotary Kiln a month. A total of over 150 "Traylor-Made" kilns, with a combined length of more than six miles, are currently engaged in the processing of some 21 different products. Proved Traylor advantages such as all-welded shells, full-floating riding rings, single support type roller bearings are pointing the way to profitable production for mining men all over the world.

Traylor Rotary Kilns are custom-engineered and built to individual specifications for each installation. Sizes range from the smallest diameter and length up to 12′ in diameter by 450′ in length. Send for Traylor Kiln Bulletin #1115 which contains complete description, illustrations and specifications. Copy is yours on request.

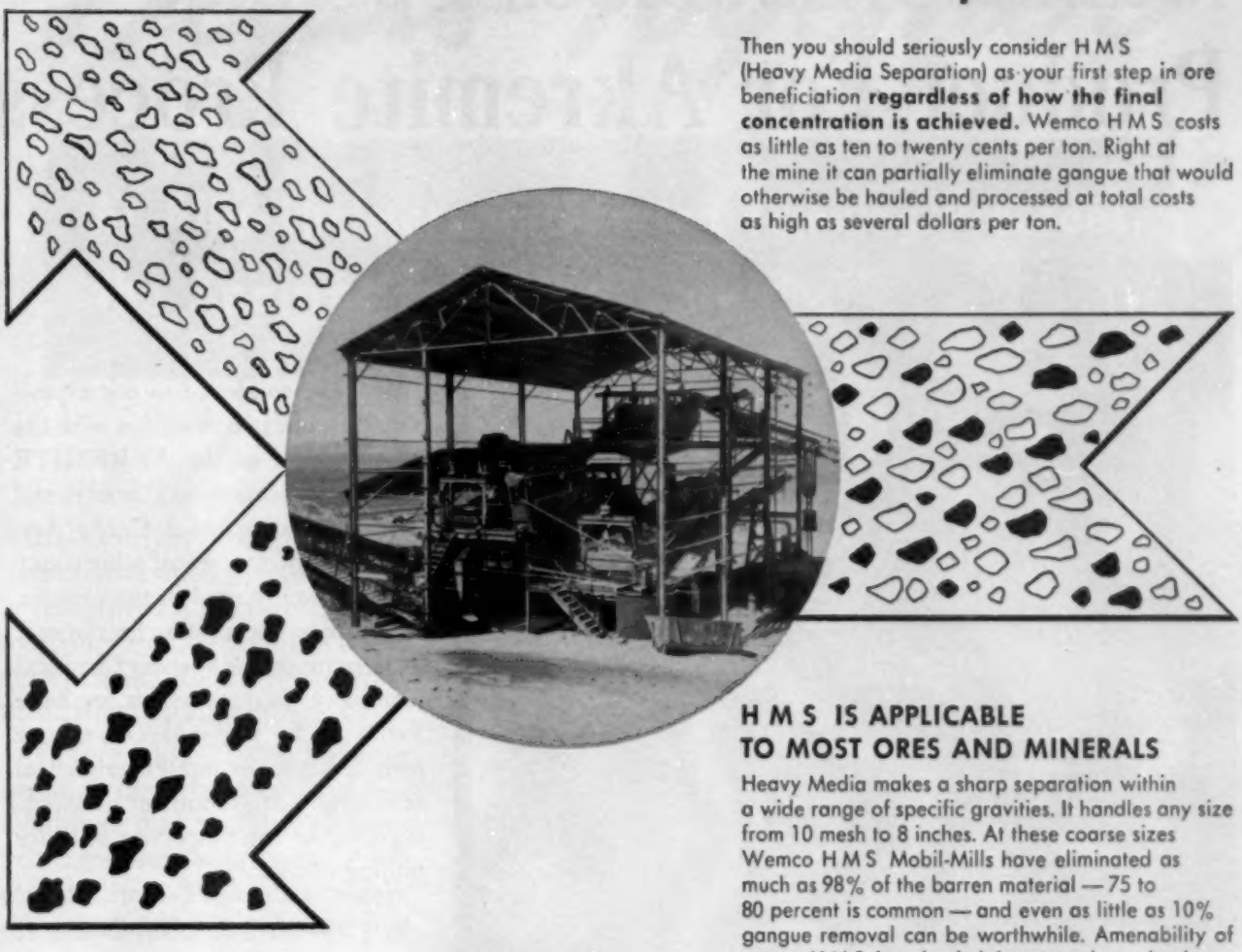
TRAYLOR ENGINEERING & MFG., CO.
794 MILL ST., ALLENTOWN, PA.
SALES OFFICES: New York • Chicago • San Francisco
Canadian Mfrs: Canadian Vickers, Ltd., Montreal, P.Q.

A Traylor leads to greater profits



Primary Gyratory Crushers | Rotary Kilns | Secondary Gyratory Crushers | Ball Mills | Jaw Crushers | Apron Feeders

WOULD YOU SPEND 15¢ to save dollars per ton?



Then you should seriously consider H M S (Heavy Media Separation) as your first step in ore beneficiation **regardless of how the final concentration is achieved.** Wemco H M S costs as little as ten to twenty cents per ton. Right at the mine it can partially eliminate gangue that would otherwise be hauled and processed at total costs as high as several dollars per ton.

H M S IS APPLICABLE TO MOST ORES AND MINERALS

Heavy Media makes a sharp separation within a wide range of specific gravities. It handles any size from 10 mesh to 8 inches. At these coarse sizes Wemco H M S Mobil-Mills have eliminated as much as 98% of the barren material — 75 to 80 percent is common — and even as little as 10% gangue removal can be worthwhile. Amenability of ores to H M S is a simple laboratory determination. Wemco offers this service.

WEMCO'S H M S MOBIL-MILL IS A PROVEN COST SAVER

The Wemco Mobil-Mill is H M S in its most practical form. The cost is predetermined and low because it is a complete plant that is pre-engineered and pre-fabricated. It can be assembled close to the mine (or even underground). And, the Wemco Mobil-Mill is so thoroughly proven in design that it operates from the first day. Mobil-Mills are available to fit your problem exactly. Capacities range from 5 to 500 tons per hour.

Wemco has built over 50% of all the H M S plants in use today. This experience can help you. Wemco welcomes your inquiry.

WEMCO®
WESTERN MACHINERY COMPANY

DEPT. C-2214, 760 FOLSOM STREET • SAN FRANCISCO 7, CALIFORNIA

50 CHURCH STREET • NEW YORK, NEW YORK
129 ADELAIDE STREET WEST • TORONTO, CANADA
20 BOULEVARD MALESHERBES • PARIS (8e), FRANCE

Representatives in principal cities of the United States and Canada and in major countries throughout the world.

Maumee Endorses Spencer Product For Akremite Process

Bank-shooter charging drillhole with Akremite, Maumee Mine No. 20.

"We have employed in our experimental work in connection with the development of the AKREMITE Blasting process several grades and types of Commercial Grade Ammonium Nitrate, all of which may be successfully used in the process. Maumee has been using for the past year, or more, the Spencer Chemical Company product which we have found to be well adapted to our own use and in our experimental testing at a large number of shooting jobs on the properties of other mining companies."

HUGH B. LEE, President
Maumee Collieries

The principal material in the manufacture of Akremite is ammonium nitrate. Spencer Chemical Company, one of the world's largest producers, has developed a Commercial Grade Ammonium Nitrate especially for the Akremite Blasting Process. Spencer is prepared to supply your needs.

Please write or phone for further information.

SPENCER CHEMICAL COMPANY

610 Dwight Building • Baltimore 6600

Kansas City, Missouri

Heads Together

At Allis-Chalmers, Integrated Thinking Precedes the Application of Your Integrated Equipment

Allis-Chalmers designs and builds diversified yet completely integrated lines of processing machinery as well as electrical generation, distribution and utilization equipment.

Take a look at the various product departments at Allis-Chalmers and you'll find engineering offices set up for *each* product line. Peek into conference rooms and chances are you will see members of these specialized staffs huddled on application problems . . . exchanging ideas . . . correlating specific know-how and skills.

This proven approach — for which Allis-Chalmers has long been famous — results in truly integrated equipment . . . installations with the various components matched for maximum efficiency at low cost. A-4728

MORE ABOUT ALLIS-CHALMERS INTEGRATION ON FOLLOWING PAGES.

ALLIS-CHALMERS

Milwaukee 1, Wisconsin

Allis-Chalmers

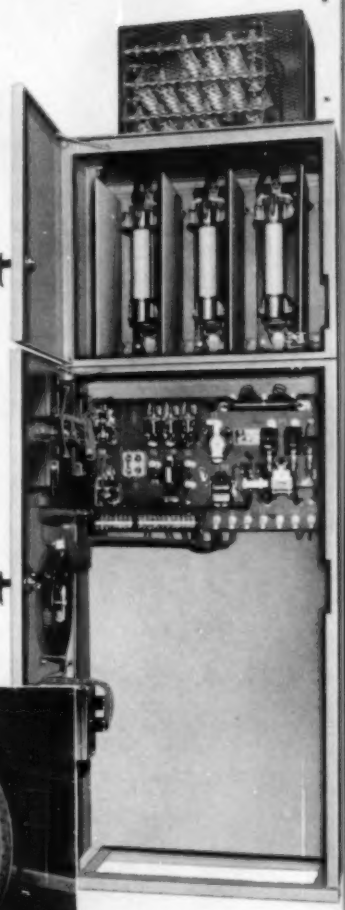
Teamed Up for

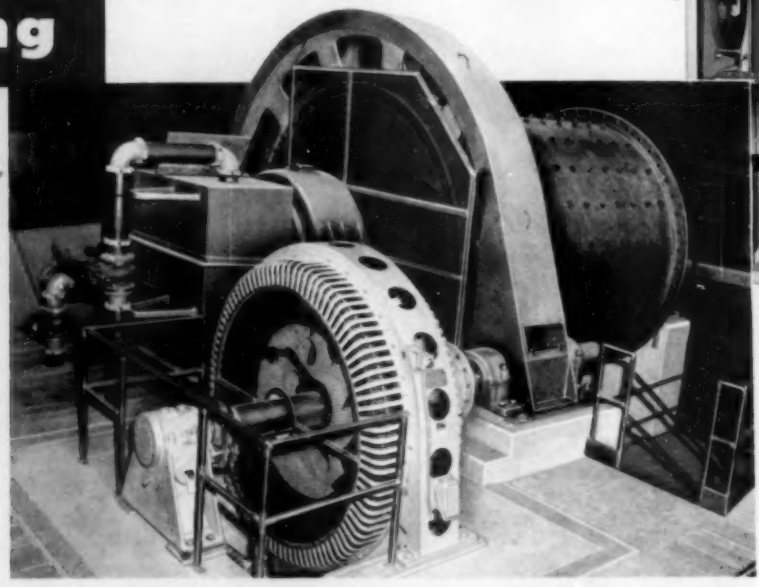
Grinding

BEFORE A RECOMMENDATION IS MADE, requirements and variables are given a careful going over by an Allis-Chalmers team comprised of *grinding*, *motor* and *control* engineers. Characteristics of material, capacity, feed preparation, balance of gradations, torque characteristics, system power factor needs, control requirements are some of the many factors evaluated. Experience has proved that this thorough pre-application investigation and preparation pays off to the purchaser . . . *pays off in maximum capacity of desired product per cubic foot of mill volume.*

A Typical Integrated Grinding Mill Installation

In a recent application, the mill installed was a 10½ by 12-foot Allis-Chalmers diaphragm ball mill. The close diameter-length ratio is an important factor in producing the highest possible capacity per unit of power. Driving the mill is a 900-hp, 4000-volt, 257-rpm, .8 pf Allis-Chalmers synchronous motor. By providing desired power factor correction, this motor reduces power cost. The Allis-Chalmers starter is specially engineered to provide protection under all conditions of grinding operation.





Modern Electrical Distribution Systems Cut Costs

Allis-Chalmers unit substations can be strategically located to bring high voltages near load centers with resultant economy in cable cost, minimum line loss and efficient voltage regulation. Illustrated is Allis-Chalmers switchgear installed underground where it serves motors driving crushers, compressors, shovels and drills.

At Allis-Chalmers, electrical and mechanical engineers combine their skills and knowledge in coordinating the electrical distribution system with processing equipment when working out an efficient product flow.

This integrated effort results in maximum plant efficiency — reduces installation and power costs.

Equipment

Profitable Production

TODAY, WITH SUCH FACTORS as high kw consumption, frequent lengthy outages and costly maintenance disturbing the profit picture, the advantages of integration deserve prime consideration. For example, let's take the problem of cutting cost in a crushing installation.

Special Control Circuit

Drawing on 75 years' experience in building and applying crushers, Allis-Chalmers control *and* crushing engineers developed a control circuit designed to cut costly downtime for the crusher installation shown below. In this circuit, motor overload protection is provided by *two* sets of thermal overload relays. One set operates at slight overload to sound warning. The second set stops the motor when temperature reaches the danger point.

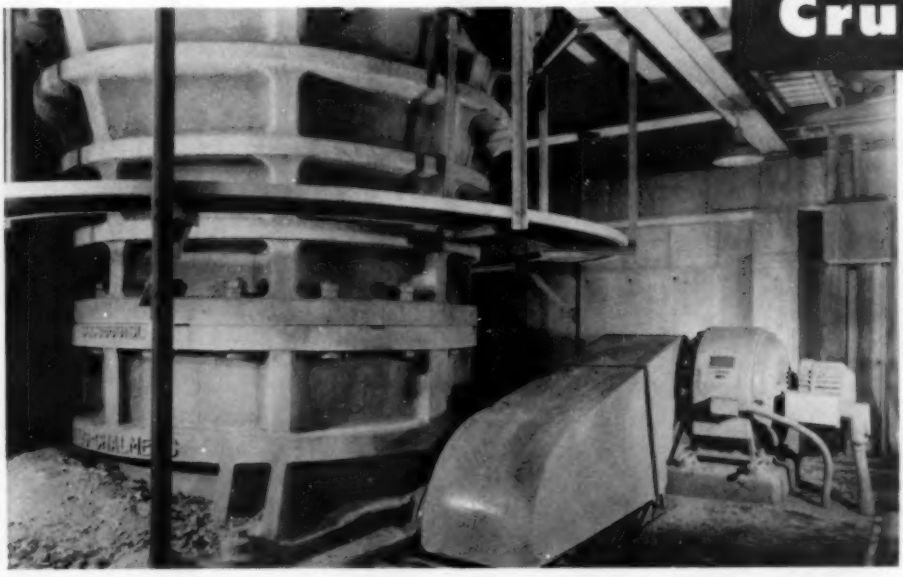
Because of high starting torque and frequent starting under load, an Allis-Chalmers wound-rotor motor is used. In calculating hp requirements, the factors of crushability, ratio of reduction, product size and specific gravity are evaluated.

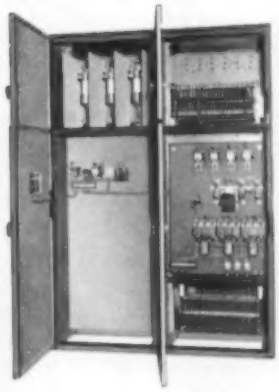
Flexibility in the Crusher

The crusher is the *Superior* gyratory crusher which features hydraulic positioning of mainshaft and mantle. This control facilitates emptying crushing chamber in case of power failure or other emergencies. It also compensates for wear on concaves and mantle and, when required, changes product size instantly. In Allis-Chalmers gyratory crushers, changing eccentricity, speed, or shape of chamber varies capacity and product size. This flexibility permits synchronizing crushing with other operations.

Superior is an Allis-Chalmers trademark.

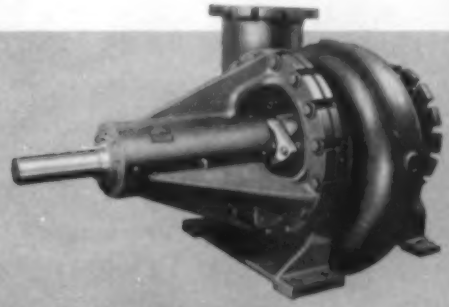
Crushing





Solids Handling Pump Built to Resist Abrasion

Here is a pump specifically designed to meet the problems of mineral processing. Rugged construction featuring the use of abrasion-resisting materials provides longest possible service life. Because some wear is inevitable in handling mineral solids in suspension, inspection and maintenance have been made easy.



AC ALLIS-CHALMERS

ALLIS-CHALMERS

Your *Dollar Buys More* when you invest in Allis-Chalmers Integrated Equipment

Because:

- Integrated units or processes evolve from a co-operative engineering effort — all Allis-Chalmers components are matched for top efficiency.
- New as well as *existing equipment* is integrated into a smooth, productive, profitable operation.
- Allis-Chalmers assures undivided responsibility for performance — there is no "buck passing" as frequently prevails when components are purchased from more than one source.
- No other company can provide the background of experience gained through the years of solving thousands of equipment integration problems . . . in research...in testing...in pilot plant operation.
- Modern laboratory facilities, periodic equipment checkups and fast emergency service from a large stock are always available.

Cost is more than a matter of price tag. Be sure you are getting all the above advantages.

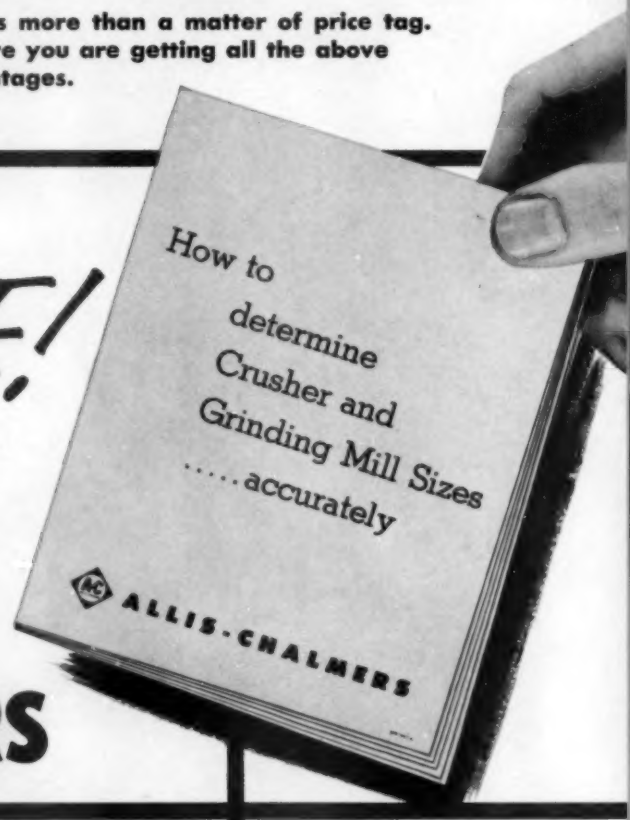
Only from Allis-Chalmers

. . . and it's *FREE!*

Nowhere else can you get this valuable book at any price!

The Third Theory of Comminution, or *work index* method, is a compilation of factual data on crushing and grinding obtained in over 35 years of field and laboratory testing. Correlating this information made it possible to establish a consistent common factor called the *work index*. Knowing the *work index*, you need only apply a given equation to determine required power input. The calculated power input enables you to select the proper crusher or mill for your job.

This practical formula, together with more than 1200 tabulated work indexes, is now available in a 72-page bulletin (07R7995). For your cost-free copy, see your Allis-Chalmers representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.



ALLIS-CHALMERS

ALLIS-CHALMERS — *INDUSTRIAL EQUIPMENT DIVISION* — **Milwaukee 1, Wisconsin**

Send me the following bulletins:

- 25C6166D, a mining industries catalog
- 07R7995, Third Theory of Comminution

I would also like bulletins on: _____

Explanation of Process or Problem: _____

_____
(Type of Equipment)

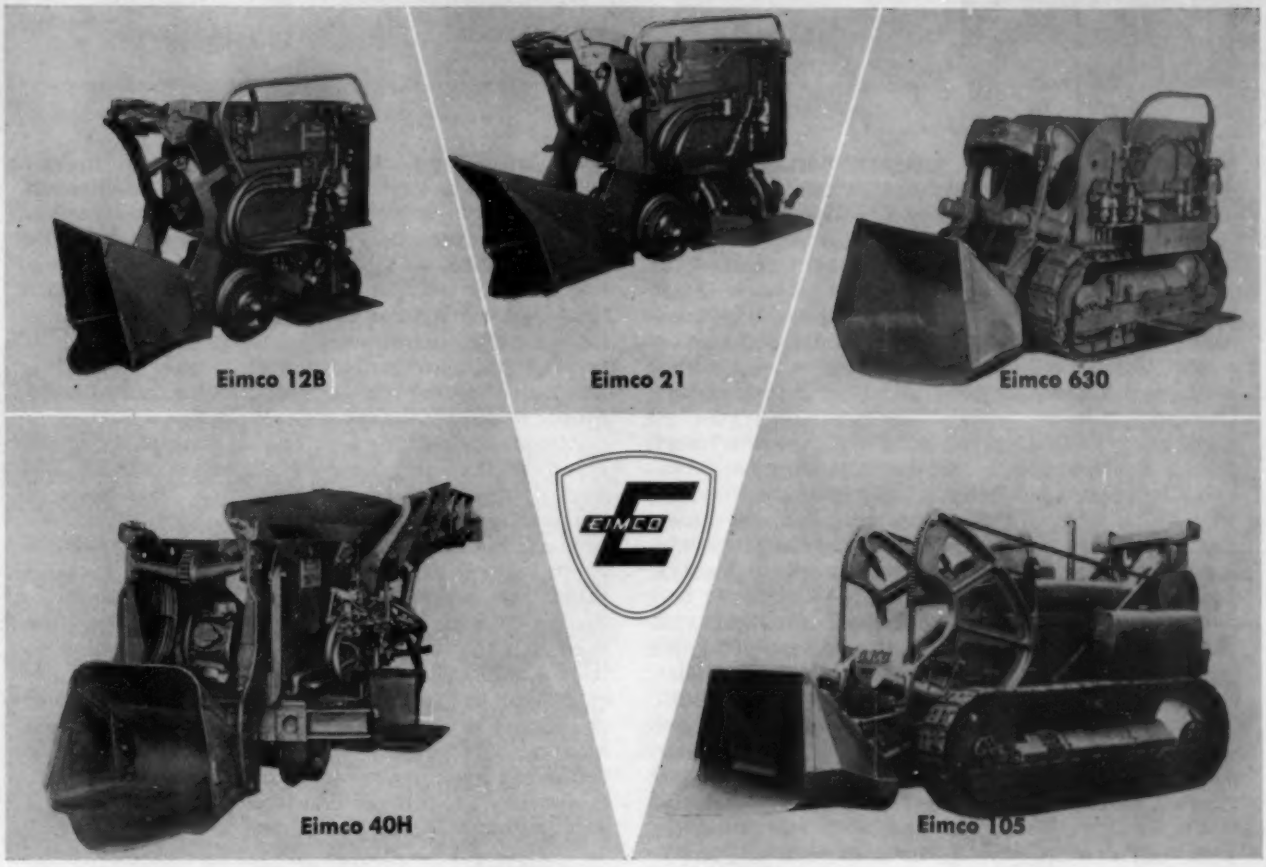
Name _____ Title _____

Company _____ Address _____

City _____ Zone _____ State _____ A-4728

WRITE FOR LITERATURE

Bulletin 25C6166D covers all equipment manufactured by Allis-Chalmers for the mining industries. Individual bulletins covering specific equipment lines are also available.



THERE'S AN EIMCO TO FIT YOUR LOADING JOB

There is an Eimco loader for your loading job. Small or large tunnels, drifts, slopes, inclines, haulage ways, overburden, cleanup, road building, clearing slides or any loading job that requires speed, economy and continuous operation with minimum machine attention.

Eimco loaders are available with wheels for rail type operation and crawler mounts for trackless work. They are self propelled by air, electric and diesel motive power, depending on their type of application.

Eimcos are proved loaders — more of them are in daily use on hard rock mining jobs throughout the world than all other brands of mechanical loaders combined. Many of these have been in continuous operation for more than 20 years.

An Eimco is always your most economical loading machine. Write for details.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Tex. Birmingham, Ala. Duluth, Minn. Kellogg, Ida. Baltimore, Md. Pittsburgh, Pa. Seattle, Wash. Pasadena, Calif. Houston, Texas Vancouver, B. C. London, England Gateshead, England Paris, France Milan, Italy Johannesburg, South Africa

B-184

DESPITE the greatest one-day market set-back since 1929, onward and upward were the labels for what may come to be known as the *surprise* boom of 1955. As third-quarter reports rolled in it was apparent that the year might easily set new all-time economic records across the board. Earlier fears that a slackening of the pace in home building, general construction, and auto production might come in the summer doldrums and initiate at least a leveling if not a dip in general business proved unfounded.

Certainly the whacking car output and the forest of new homes going up were major economic props in 1955. Houses also stimulated hard goods buying. How much credit for the continuing auto purchases should go to aggressive merchandising and engineering changes and how much to money in people's pockets was controversial. Similarly a disparity between the number of new household formations and the rate of housing starts raised questions as to the importance of new concepts in home merchandising vs ease of obtaining long-term mortgage credit. Tightened bank credit in connection with mortgages would test this last point—some felt that tighter money would squeeze out only the marginal and potentially bad risk home buyer.

Car loadings, electric output, steel rate, oil production and other indices made good reading, but they were history. They still only provided a firm picture of the past, although often relied on for gaging the immediate future. More promising, however, were such items as construction contracts outstanding—ahead of similar months last year—and backlogs of orders on mill books. This last item is less well represented statistically, but trade press reports and word-of-mouth both stressed fat futures books. Polls of purchasing agents checked these stories out. The immediate economic future looked so solid the most recent quarterly economic outlook report from the U. S. Chamber of Commerce almost bubbled with optimism. Only two clouds marred the "blue skies from now on atmosphere": farm income was down and consumer credit and mortgage debt were high. A few die-hards reminisced about the late 1920's when these two things were also true, high credit and low farm income. It was hoped in most quarters that the parallel ended there.

◆◆◆◆◆◆

IF cars and houses had built a boom the mineral industry was sharing it. There were exceptions, but sparked by the special situation which found copper at a 90-year high, metal prices were also on the upturn. Even mercury reversed its slide from abnormal highs and appeared to be settling at $250 to $275 per flask. Rumors persisted of black markets in one or two of the rare metals. Hard goods or durables had run ahead of the soft goods market and this contributed to strength of metals demand and prices, but something else was adding spine to the market—inventory buying.

In fact purchases for inventory alone might carry the market for a short time, because stocks were already low at the start of the boom. How the situation came about was simple to see, in retrospect. Mills and manufacturers tended to overestimate the recession last year, and equally underestimated the boom in 1955. Coupled with a pessimistic economic outlook was a fairly common view that metal prices were "too high." With these two promises it was easy to justify paring inventory last year, especially if it favored the appearance of the financial statement. The rate of recent consumption just had not allowed people to rectify earlier miscalculations.

Almost any period of high metal consumption provides illustrations of another factor in mineral industry supply and demand dynamics. That factor is the relatively slow rate at which significant new production can be created. The past 15 years have given several examples of the fact that a complicated new product can be designed, plants built, tooling created, and production realized in less time than it takes to find, develop, and start producing from a big mine. This is especially true if the property is underground and complicated beneficiation or refining is required. It is interesting to speculate how much of present consumption of key metals is being met by increased facilities initiated in the atmosphere of shortages and encouragement to production that followed the start of the Korean war.

◆◆◆◆◆◆

WHILE most of us were occupied with the present, Fundamental Investors Inc., a mutual fund, was asking a cross-section of business leaders to forecast American life two decades hence, in 1975. From the springboard of present prosperity these leaders forsee startling production gains.

A composite of the views of these 26 business spokesmen visualizes an economy in 1975 where Americans will work 6 hr less per week while taking home 25 pct more. Weekend drivers will have 80 million automobiles available to clutter up the not so open road. These 80 million cars will have a population of 213 million to transport, and California will have the largest population of any state. Employment will be at a level of 85 million, as compared to the present record 65 million.

By 1975, according to these leaders, Americans will go to school longer, more women will work, more people will be stockholders, and they will have more large corporations to own a share of.

Specific quotations of interest in the area of steel and other metals came from the presidents of U. S. Steel, Bethlehem Steel, and Kaiser Aluminum & Chemical.

A. B. Homer, president of Bethlehem Steel Co., suggested that the steel industry will need to increase ingot capacity at an annual rate of about 4 million tons over the next two decades. Henry J. Kaiser, president and chairman of Kaiser Aluminum & Chemical Corp., points out that "since 1940 shipments of steel have grown 59 pct and aluminum shipments have grown 780 pct. . . . This age of atomic energy, aviation, electronics, new metallurgy, chemistry, and new technology, has jet-propelled us into a chain reaction of progress."

Paralleling Mr. Homer's views on increasing steel output, Clifford F. Hood, president of U. S. Steel Corp., suggests that "we are going to have to add 50 million tons to the industry's ingot capacity in the next 20 years. This averages out to one giant new steel mill about every year. . . . Under the circumstances, it is difficult to be anything but confident and optimistic about the future."

◆◆◆◆◆◆

GOING from present prosperity and expressions of confidence in the future to a more specific item, the Machinery & Allied Products Institute has estimated the present capital investment required by U. S. business to employ one worker at $12,500. Hitherto figures have been available for a single business or for one segment of an industry, but this study provides an analysis of business as a whole. The study covers private business including agriculture but excluding property ownership.

The Institute points out that durable productive facilities, industry's plant and equipment, are wasting assets. The large annual investment required merely to offset this wastage is estimated to run in excess of $25 billion a year. Translated into individual jobs this mean that it takes an average annual investment of $450 per worker to maintain jobs already in existence.

To offset an estimated 400,000 annual increase in the number of jobs, an additional $5 billion capital investment is required. Further, an advancing economy with productivity gains increases the rate of investment per worker. The Institute estimates this improvement requirement at $10 billion per year.

Summing up these figures it is apparent that if business as a whole is to absorb growth in private labor force, offset the current consumption of fixed assets, and provide for normal growth of investment per worker, it must find $35 to $40 billion each year in long-term capital. Where this will be realized is from depreciation allowances, retained earnings, new equity financing, and long-term borrowing.

In addition to an unprecedented volume of the tools of production, there is a sizable investment in working capital, such as inventory, receivables, cash, and marketable securities. The Institute estimates that at 1955 prices the per worker capital investment by type of funds is as follows:

Plant and Equipment (after depreciation)	$4,900
Land and Financial Resources	2,400
Current Assets	5,200
	$12,500

All of the foregoing assumes a going concern—with used facilities. For a new firm or a separate expansion project the picture changes and sums grow larger. In this case the total investment per worker might reach $17,500, of which about $15,000 would have to be financed with new long-term capital. It appears fairly obvious that the financial houses will also share in the growing economy if these figures have any validity.

ALTHOUGH the mineral industry as a whole appeared to be sharing in prosperity the industry was not without its problems. Nor was every producer of every mineral commodity equally favored by the times. Gov. Goodwin J. Knight of California has been concerned with the industry's problems, and interested in attempts to find solutions, especially to those requiring Government action or assistance. Following discussions with mineral industry representatives he got in touch with Governor Russell of Nevada, chairman of the Western Governors Conference. The result has been the scheduling of a Western Governors Mineral Policies Conference to be held in Sacramento, Calif., Nov. 7 and 8, 1955. Following this meeting the Western Governors Mining Advisory Council meets November 9 and 10 to place the conference recommendations in final form.

In addition to the 11 western states represented by the Governors group, invitations to the Sacramento conference have been extended to South Dakota and Alaska. Governor Knight has asked the California State Dept. of Natural Resources and the State Mining Board to assist in developing conference plans in cooperation with representatives of the mining and mineral industries of the West. Committee work is already under way.

Objective of the conference is to create a forum to analyze the problems involved in creating and maintaining a healthy domestic mining industry. From this forum it is hoped to develop fundamental national mineral policies, and to provide a continuing effort toward the establishment of these policies by Congress and the Administration. It is felt by the sponsors that such policy recommendations would be more fully effective on the national level with the endorsement of the Western Governors Conference. It is also hoped that under the sponsorship of state governments the policy recommendations can be kept free from undue influence by special interests.

Each of the governors of the western states appoints an advisory group on the state's mineral industry affairs. These state delegations in turn comprise the Mining Advisory Council of the Western Governors Conference. The present chairman of the council is S. H. Williston, vice president, Cordero Mining Co., Palo Alto, Calif., and Miles P. Romey, manager, Utah Mining Assn., Salt Lake City, is vice chairman.

The California delegates to the Western Governors Mining Advisory Council are also serving as the executive committee for the conference on November 7 and 8. The chairman of this nucleus group is DeWitt Nelson, director of the California Dept. of Natural Resources, Sacramento. The other members are: P. R. Bradley, Jr., chairman, California State Mining Board, San Francisco; W. C. Browning, member, State Mining Board, Los Angeles; Ian Campbell, executive officer, Div. of Geological Sciences, California Institute of Technology, Pasadena; J. R. Holman, Pasadena; L. L. Huelsdonk, member, State Mining Board, Downieville; Tom Lyon, San Diego; Henry Mulryan, president, Sierra Talc & Clay Co., South Pasadena; S. H. Williston, vice president, Cordero Mining Co., Palo Alto; and Ray B. Wiser, president, Walkeng Mining Co., Berkeley.

. . . from the ARCTIC to the EQUATOR

. . . from the FAR EAST to CONTINENTAL EUROPE

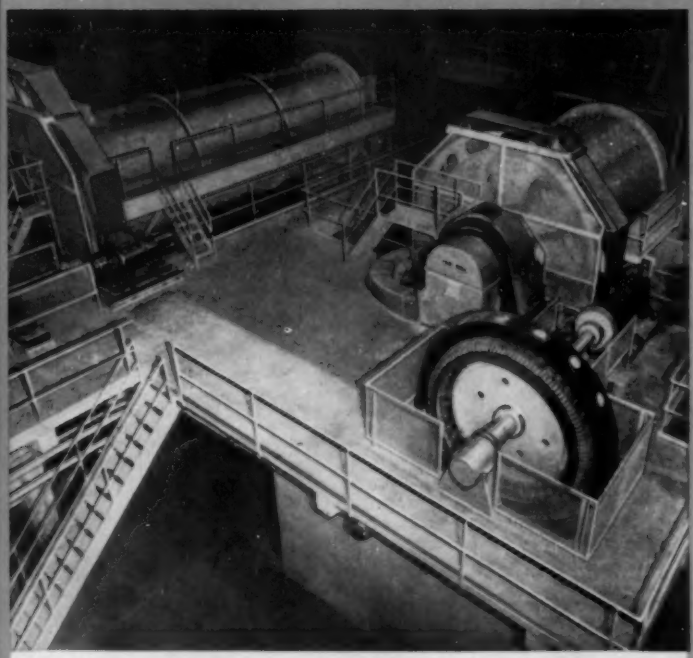
NORDBERG

are Industries' choice for the efficient

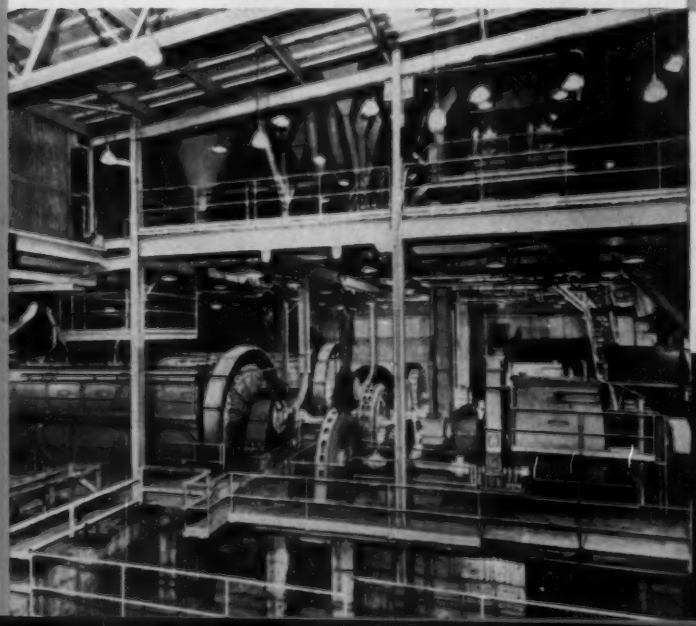
These six Nordberg 10'8" by 17' wet grinding Ball Mills efficiently serve a large Taconite reduction plant.

GRINDING MILLS

reduction of ORES, CEMENT and MINERALS



These two views show eight Nordberg Grinding Mills used for raw and finish grinding in the plants of a leading cement producer. Above is a 10'8" by 16' Ball Mill and a 9'6" by 32' Compartment Mill. Below are two 10'8" by 17' and two 9'6" by 11' Ball Mills, together with two 8'6" by 36' Compartment Mills.



MORE than half a century of progressive engineering achievement, combined with quality production in modern manufacturing facilities, have won for Nordberg a foremost position in the field of heavy machinery manufacture.

This is evidenced by the universal acceptance which Nordberg Machinery has received by most of the Mining and Mineral processing industries throughout the world.

Typical of this heavy machinery is the complete line of Nordberg Grinding Mills for raw and finish grinding of cement materials, the fine reduction of metallic and non-metallic minerals and for numerous other processes where friable material must be comminuted to fine sizes.

Nordberg manufactures Ball, Tube, Rod and Compartment Mills, of grate, overflow and peripheral discharge types for wet or dry grinding service, in sizes ranging from 6 feet to 13 feet in diameter, and up to 50 feet in length.

For large or small operations, you can depend on Nordberg Machinery to deliver maximum output at lowest possible cost. Write for further information. *NORDBERG MFG. CO., Milwaukee, Wis.*

SYMONS . . . *a registered Nordberg trademark known throughout the world*

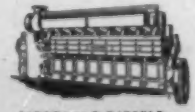
SYMONS GYRATORY CRUSHERS

SYMONS CONE CRUSHERS

SYMONS VIBRATING GRIZZLIES and SCREENS

SYMONS V-SCREENS

NORDBERG KILNS and COOLERS



NORDBERG DIESELS— 10 to over 12,000 H.P.

©1955, Nordberg Mfg. Co.

GM155

NORDBERG

MACHINERY FOR PROCESSING ORES and INDUSTRIAL MINERALS

NEW YORK • SAN FRANCISCO • DULUTH • WASHINGTON
TORONTO • MEXICO, D.F. • LONDON • JOHANNESBURG

The two 6-cell No. 18 Special Denver "Sub-A" Flotation Machines at Arizona Barite Co. Larry Mathis, Mill Superintendent, adjusts the pulp level in each cell by hand-operated weir gates.

Arizona Barite Co. has replaced no parts on Denver "Sub-A's" in operation since 1948

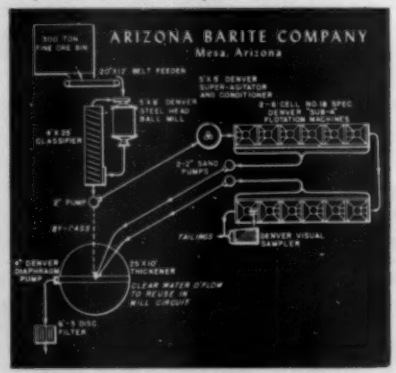
"Arizona Barite Co., Mesa, Ariz., installed a 6-cell No. 18 Special (32 x 32) Denver 'Sub-A' Flotation Machine in June, 1948, for roughing. At the same time, we added a second 6-cell No. 18 Special Denver 'Sub-A' Flotation Machine for cleaning. Due to the conditions of the ore, this setup was not practical, so the 'Flexibility' feature of the Denver 'Sub-A' Machines was used to hook them in tandem.

"Since the original installation, no wearing parts have been replaced after 47,450 hours of continuous operation. The only maintenance has been replacement of V-belts and lubrication. We estimate another two years' wear on impellers before replacement is necessary."—Larry Mathis, Mill Superintendent.

This is a specific example of one of the reasons why mill operators depend upon Denver "Sub-A" Flotation Machines for hard, continuous operation, as well as high metallurgical efficiency. The same high profit operation is available to you.

If you are interested in the low maintenance features and metallurgical efficiency features of Denver "Sub-A" Flotation Machines, write for DECO Bulletin No. F10-B81. If you are interested in the complete story on "Benefication of Barite at Arizona Barite Company," write for Engineering Notebook Bulletin No. M4-B56.

An interesting note here is that the Denver "Sub-A" Flotation Machines are operated in series and each cell produces a finished $BaSO_4$ product without cleaning or recleaning, due to the selective action of the Denver Flotation Machine. A higher grade product can easily be made by cleaning the concentrate. Part of the present cells could be devoted to the cleaning action when necessary. This flexibility enables them to easily take care of any changing requirements in their product.



*

*The Denver Visual Sampler, installed at the tail end of the flotation section, paid for itself in two weeks.

DENVER MACHINES PAY OFF

"The firm that makes its friends happier, healthier and wealthier"

DECO FLOTATION ENGINEERS — DENVER EQUIPMENT COMPANY 24 HOUR SERVICE

DENVER EQUIPMENT COMPANY

1400 17th Street • Phone CHerry 4-4466
Denver 17, Colorado

DENVER • NEW YORK • CHICAGO • SALT LAKE CITY • TORONTO • VANCOUVER • MEXICO, D. F. • LONDON • JOHANNESBURG

WILL future geology students have to add skin diving to their course of study? Probably not, but a group of geologists have formed Geological Diving Consultants in San Diego. This organization serves the needs of oil companies for underwater geological mapping along the Continental Shelf. Increased offshore oil exploration has brought about the necessity of supplementing seismographic data and these submarine rock hounds can do the job at depths as great as 150 ft by donning flippers, face mask, and rubber suit. One point is positive: Few will disagree with their reports. The offer to "Come on down and take a look yourself if you don't believe me," will stop most doubters.

▲

LOST for 165 years, the first Letters Patent issued by the U. S. Government was recently discovered. *The PCA Miner,* published by the Potash Corp. of America, carried a reproduction of the document in its July issue. Why was it in *The PCA Miner*? U. S. Patent No. 1 was for an improved process for the manufacture of "pot ash" and "pearl ash." Granted July 31, 1790 to Samuel Hopkins of Philadelphia, it was signed by George Washington.

▲

IF you don't want to lose valuable papers around the office, turn your wastepaper basket over when you do important desk work.

That's the advice from Minneapolis-Honeywell's chief accountant, Al Rudell, who solved that "misplaced-ticket" problem during a recent five-week inventory. During that period approximately a quarter of a million inventory tickets poured into the cost accounting department. All were priced, extended, posted, audited, and totaled for comparison with accounting ledgers.

To prevent losing tickets, Rudell ordered wastepaper baskets set aside. All wastepaper was tossed on the floor. Then in the evening all the wastepaper from the floor was carefully sorted to make sure it contained no tickets.

Not one was lost.

▲

ONE doesn't always remember how impure and imperfect many taken-for-granted materials are until he sees a release such as the one from Westinghouse announcing laboratory manufacture of perfect iron in crystals. Previously available for study only in microscopically visible crystals, the new specimens are up to a couple of inches by a thousandth of an inch wide. Tensile strength of the product is about 1 million lb—ten times that of ordinary iron wire and three times that of the steel in piano wire.

WE recently received the following information via press release from (name withheld): "Why the need for such high temperatures? The efficiency of a heat engine increases with the available temperature drop between the input and *putput* sides of the engine." Either they better start putting better mufflers on those engines or get the kids out of the engineering department.

▲

SOMETIMES it is nice to think that your information and knowledge of a particular field of endeavor is better than the average, but occasionally incidents arise that positively put one to shame. We reported last month on a short tour of the Colorado Plateau where we had been seeking the inside dope on finding and mining uranium. When returning to the office, we were confident little had escaped our attention.

However, it was reported on August 31 in the *The Norwalk Hour* that uranium had been found in Connecticut by a ceramics engineer. This news item stated that according to AEC findings, the ore contained up to 1.5 pct of U_3O_8. If this find and the grade of ore is authentic, it could be a world-shaking discovery.

But the ironical thing about it is that although we (a traveled quasi expert) live in Norwalk, we have not acquired any financial interest, nor have the slightest idea where Henry Von Stahl found the stuff. We have had numerous inquiries from the neighbors and find that the only answer is to run the lawn mower faster and pretend we don't hear.

▲

THIS does not (although it could) have any bearing on the previous discussion, but we found a good definition of research: A straight line drawn from the tangents of several assumptions to the center of a foregone conclusion. Or should it be confusion?

Speaking of research, our own personal search has uncovered these facts about the changes in Washington under the present administration:

"The morning traffic peak across the 14th Street Bridge over the Potomac now occurs 25 minutes earlier than it once did."

"The Government now owns 1380 fewer automobiles."

"It uses three million sq ft less office space."

"It has 148,000 fewer employes."

"It uses 120,000 lb less coffee per month in Government cafeterias."

"Three years ago I always got a choice seat on my 7:30 am bus, but not any more, and usually several loaded buses pass me up. There's a strong movement to eliminate all the temporary buildings along the Mall—some were temporary in World War I."

THE NEW D7, D8 and D9

here's what they can mean on your job

The new 286-HP CAT* D9 Tractor

Choice of torque converter or oil clutch drive. First track-type tractor with Turbocharger. Completely new 286-HP engine. "Live-shaft" drive for rear-mounted equipment. Many other important features.

The new 191-HP D8

With torque converter (Series D). With exclusive oil clutch drive (Series E). Completely new 191-HP engine. "Live-shaft" drive for rear-mounted equipment independent of flywheel clutch. New easy-working controls. Many other improvements.

The new 128-HP D7 Series C

Gear-type balancer gives six-cylinder smoothness. New 128-HP engine. Drawbar pull now 28,700 lb. maximum. New starting engine for simpler, easier operation. Track shoes hardened by "water quench" process. And many other important advances.

The year's biggest news on tracks: Caterpillar's three great new Diesel Tractors.

They're big news because they give you greater power and better performance than ever before.

The D9 and D8, for example, give you your choice of torque converter or exclusive oil clutch drive so you can best match your machine to your own job requirements.

All three give you features like one-piece frame-steering clutch case assemblies, and track shoes specially hardened by a new "water quench" process which means longer shoe life.

All three are easier to operate, with simpler, more powerful starting engines, easier working controls and other improvements.

They're easier to service, too; an exclusive trouble-free oil clutch, separately removable power train components and a fuel system that needs no adjustments in the field are only three of many reasons why.

Better be sure you get *all* the news about the new D7, D8 and D9. Call your Caterpillar Dealer today. Or mail the coupon below.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

MAIL TODAY!

CATERPILLAR TRACTOR CO., Peoria, Illinois, U.S.A.

I'd like *all* the big news about the new D7, D8 and D9.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

THE NEW D9, D8 AND D7
—EXAMPLES OF CATERPILLAR
LEADERSHIP IN ACTION

Open pit operators in Arizona have favored the combination of 35-ton trucks and 5-yd electric shovels. Equipment of this size seems to be readily adaptable to the copper pits.

Open Pit Forum

What is the Economical Point of Replacement Of Pit Equipment in the Southwest Copper Pits?

by B. R. Coil

ONE executive writing on capital equipment replacement stated: "We keep extremely close watch over repair costs and when we reach the point of uneconomical operation, we replace the machine." This, of course, is most elementary, but a very basic premise. However, it seems advisable to set forth several equally obvious principles, so that all discussion will start from the same point. The subject is intended to deal with the point of uneconomical operation due to high operating costs in general and high repair costs in particular. This is not concerned with a similar problem of high costs because of an insufficient number of machines, be they trucks, shovels, or dozers.

Southwestern operators keep unit costs on all mine operations. For auxiliary equipment, the popular unit seems to be the cost per operating hour. For heavy duty haulage units, there is a difference of opinion as to the most useful unit—cost per ton hauled, cost per ton-mile, or cost per operating hour. Since copper mine operators must check ore production against a mill scale, probably the most popular unit is the *cost per ton hauled.*

B. R. COIL is Manager of the Miami Copper Co., Miami, Ariz.

Table I. Heavy Duty Trucks
Summary of Arizona Operations

Age Years	No. of Units in Fleet							
	A	B	C	D	E	F	G	Total
Less than 4	21	16	17	27	10	8	2	101
4-6	—	2	7	—	—	—	—	9
6-8	—	6	—	—	—	—	5	11
8-10	—	—	—	—	—	—	—	—
Over 10	—	—	—	—	15	—	16	31
Maintenance Costs Kept by:								
Individual trucks			X					
Groups—Same Model	X	X		X			X	
Fleet					X	X		
Trucks taken out of service:								
No.	0	4	21	0	12	5	0	42
Average Age		6.0	6.6		10.0	11.0		
Average Hours Operated		18,000	28,478		27,000	41,000		

Any unit for costs is satisfactory in considering capital equipment replacement, the important thing is to be consistent in using the same unit in comparisons. An exchange of cost data from one property to another has very little value to the problem of capital equipment replacement, unless physical operating conditions are identical, and costs are kept in exactly the same manner.

When considering replacement of heavy duty haulage trucks, the operator must answer the question. Can I buy and pay for new trucks, and haul cheaper than I am with my present trucks?

Heavy Duty Trucks—Types of Replacement

Case No. 1—Replacement because the machine is worn out.

Case No. 2—Replacement because of obsolescense as a result of technological improvements.

If the base period for taking the capital investment into the operating accounts is established as above, then the point of uneconomical operation can be determined by formula.

Let a = Amortization per cost unit

m = Average maintenance cost per cost unit during the base period used for amortization—corrected to the current period.

M = Current maintenance per cost unit.

When M = m + a buying new trucks would be trading dollars.

When M is greater than m + a buying new trucks would show saving.

In considering a Case 1 replacement m should be available from the old cost sheets, but the amount will have to be corrected to allow for the increase in wages and parts. In a Case 2 replacement m would have to be estimated, unless actual maintenance costs were available for the given job and for the particular model of the truck being considered as a replacement.

To give a specific example of using the formula when considering a Case 1 replacement: Castle Dome purchased five 30-ton trucks in 1948. Question: Should these trucks be replaced with new trucks of a similar design and capacity? Assume a base period of three years to recover the capital cost in operating cost.

Base Period Maintenance Costs

Average from cost sheets 1948 through 1950

	Per ton Hauled
Maintenance labor	$0.01295
Truck parts, etc.	0.01861
Total	$0.03156

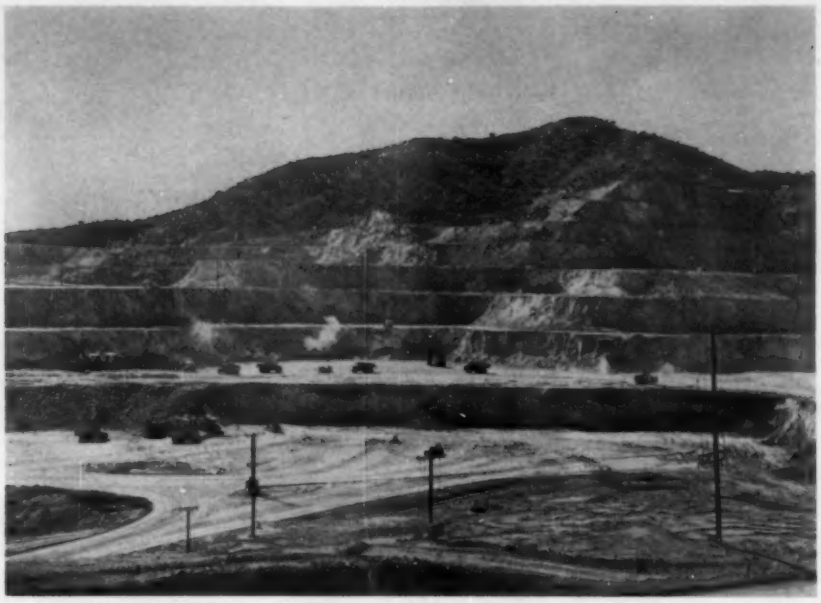
Correct base period costs to 1954 conditions

Increase labor by 28.46 pct	$0.01664
Increase parts costs by 16 pct	0.2159
m	$0.03823
Amortization of similar new trucks in three years	0.01502
$m + a$	0.05325

First six months 1954 haulage costs for the five trucks

Maintenance labor	0.01506
Truck parts, etc.	0.02188
M	$0.03694

Since M is less than $m + a$ the point of uneconomical operation has not been reached, and the purchase of new trucks is not justified.



Truck operation is advantageous in the small and medium-sized mines because of flexibility and lower initial capital cost. The gains to be made with truck haulage are being developed in most of the new open-pit mines.

Financing of equipment purchases, the subsequent depreciation for tax purposes, and the method of recovering capital costs are the function of management. Since these subjects are not problems of the operating department, they are not considered within the scope of this article. However, even though the capital costs of the new machine may never appear in the mine department's unit costs, it is a factor that must be considered in the replacement of capital equipment.

Again, using heavy duty trucks as an example, the operator realizes that new trucks must be paid for in operation, and some consistent formula must be adopted to include the capital cost in unit costs over a given period of time or over a given number of units.

Following the usual depreciation formula, the period of time could be the expected life of the new machine or the expected life of the property, whichever is shorter. However, in respect to heavy duty haulage trucks, the shorter period during which the new truck has *minimum maintenance* is preferred. Miami has set this period at three years, or about 15,000 operating hr.

For the first three years, maintenance on a new truck is low and haulage cost can absorb the amortization. At the end of three years, some major items of maintenance begin to appear, such as frame breakage, dump body repairs, and hoist overhauls. Usually during the fourth year, around 20,000 hr, the truck is ready for a complete overhaul. It is easier to achieve haulage costs if the amortization is paid off during the period of minimum maintenance costs.

Five of the seven mines listed in Table I use all truck haulage, while two are primarily rail transportation, with trucks in use for special stripping jobs. History of the open pits shows that only two were in operation prior to 1943, two started in that year, and the remaining three were put into production since that date. Of course, the newer mines have not been faced with the problem of equipment replacement to any extent.

From what meager data is available, apparently there is no relationship between "age of the truck" and "uneconomical operation." Most of the trucks purchased have been additional units rather than replacement units. Where replacements have been made, obsolescence seems to be the governing factor. The rapid advance in truck design since World War II has kept the operator constantly reviewing his haulage costs.

Common practice in the area is to keep the trucks in good repair and to rebuild them completely at

Table II. Light Trucks (1½ to 10 tons)

Mine	Total No. Trucks Operated	Trucks Replaced					
		1½ ton		2 & 3 ton		Over 3 ton	
		No.	Age	No.	Age	No.	Age
A	10	0	—	0	—	0	—
B	7	0	—	3	5.0	0	—
C	55	19	6.0	42	3.7	12	13.5
D	21	0	—	0	—	0	—
E	6	0	—	0	—	0	—
F	31	1	12.0	3	9.6	0	—
G	8	5	7.7	4	7.7	0	—
H	15	11	6.0	2	6.0	1	6.0

Questionnaire On Equipment Replacement Programs

Question No. 1: What data do you use to determine the point at which heavy duty trucks are scrapped or traded in?

Mine A—No definite data.

Mine B—Trucks have not been operated long enough to determine this as yet. The four trucks taken out of service were replaced by larger units.

Mine C—Normally when improvements can show a capital saving.

Mine D—Believe trucks will be scrapped when new developments make present truck fleet obsolete.

Mine E—Cost per hour of operation and availability.

Mine F—No trucks have been scrapped or traded in. Five trucks were retired from haulage service and used elsewhere.

Mine G—Data not conclusive.

Question No. 2: What information do you use for taking light trucks out of service?

Mine A—No definite data or time.

Mine B—After five years service the trucks in the 2-ton size range each a point where maintenance is excessive and availability low.

Mine C—General condition.

Mine D—Use service record of truck.

Mine E—This type of truck is used until they are no longer serviceable.

Mine F—Obsolescence is the principal factor. Salvage value and projected operating and repair costs for old equipment and price and estimated operating costs of the best available replacement equipment are also considered. Many of the older trucks have been used for mounting portable compressors.

Mine G—Age and hours operated with consideration given as to occupation.

Mine H—Maintenance and construction engineer's recommendation.

Question No. 3: What is the basic reasoning used for determining the useful life of bulldozers at your mine?

Mine A—No definite figure.

Mine B—Bulldozers are taken out of service after two main overhauls. This occurs at about 25,000 to 30,000 hours of operation.

Mine C—Operate 14 bulldozers, and replace two per year, using the oldest machines for trade-in.

Mine D—Plan to use cost data and repair work records on each unit to determine service life.

Mine E—Have not scrapped a tractor during the 12 years of operation. All units are rebuilt in our shop.

Mine F—Same as light trucks.

Mine G—Overhaul costs should be less than sum of operating and maintenance cost for expected life of overhaul.

Mine H—Maintenance and construction engineer's recommendation.

regular intervals. The cost of these periodic overhauls is included in the maintenance costs. The rebuilding jobs are done as spare-time work, and use the available maintenance labor. A majority of the operators agree that they get the complete overhaul for the cost of the parts and material and that trucks can be rebuilt an indefinite number of times. Thus old age has not been a reason for truck replacement in the Southwest.

The writer wishes to thank the following Southwestern operators for data and assistance: J. C. Van De Water; L. Ormsby; J. A. Lentz, Jr.; W. T. Smith; J. R. Watts; K. R. Crocker; W. E. Herkenhoff; and M. M. Stover.

Mine yard of the USBM oil shale experimental plant located at Rifle, Colo. This operation is primarily interested in the development of methods, techniques and equipment that will make oil shale an economical source of petroleum for the future.

Oil Shale Mining Program Does Two Jobs:

1. Completes Research on Large-Scale Mining Methods

2. Develops Cost Data on Oil Shale Production

by J. H. East, Jr., and C. K. Rose

PROVED oil shale reserves in the Green River formation in Colorado, Utah, and Wyoming dwarf present U. S. petroleum resources. Indications are that the appetite for petroleum products will continue to grow and that this potential source of liquid fuels and related byproducts cannot be disregarded.

As a part of its synthetic fuels program, the U. S. Bureau of Mines has opened a mine in the richer beds on the naval oil shale reserves. In addition to supplying material for retorting and refining studies, the development of methods, procedures, and equipment for mining oil shale on a large-scale commercial basis is of the greatest importance.

J. H. EAST, JR., is Regional Director, Region IV, USBM, Denver, and C. K. ROSE is Chief, Oil-Shale Mining Branch, Rifle, Colo.

The oil shale deposit of western Colorado is richer and more amenable to exploitation than those in Utah and Wyoming. About 1000 sq miles include beds of sufficient grade and thickness to have commercial value. It is estimated that this area contains about 500 billion bbl of shale oil in a 550-ft thick measure averaging 15 gal per ton.

Naval Oil-Shale Reserves No. 1 and No. 3 cover approximately 60 sq miles in the Rifle-De Beque area of Colorado. The 550-ft measure occurs on top of the Green River formation and outcrops within the naval reserve on the east and southeast in a long line of cliffs 3000 ft above the Colorado River valley. Near the bottom of this measure is a richer 73-ft section, called the Mahogany Ledge, that yields 28 gal per ton. This lower portion of the oil shale formation is the part now being developed.

Mining System

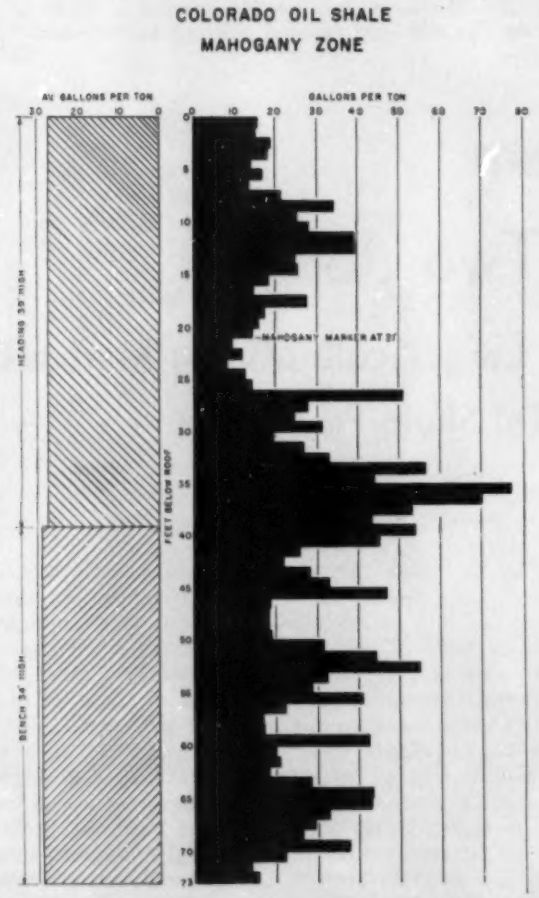
As the product to be mined has a relatively low dollar value, it was realized that for an oil shale mine to be commercial unusually low mining costs would be necessary. To attain this would require a high degree of mechanization and large production per manshift.

The physical characteristics of the Green River oil shale deposit—flat, horizontal formations that stand well without support—are unusually favorable to a low-cost, open stope mining method. USBM engineers took advantage of these natural characteristics in developing a room and pillar system of mining.

The Barodynamics Laboratory at Columbia University and the USBM Applied Physics Laboratory, College Park, Md., tested the rock. Results indicated that 60-ft wide openings supported by 60-ft square pillars would be safe. To check the calculations, a test room was opened up directly under the selected roofstone. This room reached horizontal dimensions of 80x200 ft before any failure occurred.

Original mining plans called for three levels. An advance heading 27 ft high was to be followed by two benches 23 ft high. An upper and a middle adit were driven to open up the two top levels. Pillars 60 ft square were left 60 ft apart in staggered rows for support.

Cost studies were made of mining test runs after the top heading and middle level were well advanced; they indicated that a two-level system with a 39-ft advance heading and a 34-ft bench would be more economical and would also eliminate the need for blending, as shale from either level would be of the same grade. A 39-ft advance heading was started later by taking up 12 ft of bottom in the 27-ft headings. A new, lower adit was driven to develop the 34-ft bench and open one section of the mine to the full 73 ft.



Assay log of the Mahogany ledge, a 73-ft section of the oil-bearing shale that has an average thickness of 550 ft. The Mahogany marker is about 480 ft below the top of the oil shale.

Mining Equipment

The large underground rooms permit a highly mechanized operation to be utilized and many types of specialized equipment were designed and developed.

A mobile air compressor was built to operate a multiple-drill heading jumbo. This electrically operated unit supplies 1540 cfm to the drills through short hose lines, eliminating costly pipelines and much line loss.

The drill jumbo consists of two movable platforms on a framework on a diesel truck, each platform mounting two long-feed percussion drills. Two miners drill a 96-hole round 15 ft deep in the 60x39-ft heading in an 8-hr shift.

Several types of mobile units have been designed and built for loading blastholes at height and for scaling (barring-down) operations. The most successful is a self-leveling platform on a hydraulic-powered boom, which is mounted on the bed of a diesel truck. Two men working on this platform position themselves as needed by foot-operated, remote-control switches and scale down a face 60 ft wide by 39 ft high in one shift.

Broken rock is loaded into diesel dump trucks with a 3-yd electric shovel. Bulldozer tractors are used for pushing up and for cleanup work.

Cost Estimates

Two prolonged mining test runs have been made to obtain information for cost time studies. These tests simulated the mining cycle of drilling, blasting, loading, hauling, and scaling of a large-tonnage operation. Evaluation of the data indicates that a mine producing 28,000 tpd would be an economical size.

Studies of Mining Systems

The two-level mining system being put into effect for mining the 73-ft section of oil shale is a workable and generally satisfactory one. However, there are many opportunities for improving the methods and techniques. The present system allows a stope or area extraction of 75 pct. A retreat system of mining is being considered to increase extraction. The USBM has retained L. S. Parkinson, head, mining dept., Colorado School of Mines, as consultant to make studies of alternative mining methods.

Mining Research

Roof Control

Fred Wright of the USBM made laboratory studies of the roofstone and theoretical calculations of a safe roof span under the direction of Prof. Phillip B. Bucky of Columbia University. Leonard Obert of the USBM station at College Park, Md., also studied the physical characteristics of the oil shale by another method and confirmed the results obtained at Columbia. This work indicated that openings 60 ft wide, supported by 60-ft square pillars, could be mined safely.

To check this design, a test room 50 ft wide and 100 ft long was opened directly under the roofstone.

Special test equipment was installed to take daily measurements of roofstone movement. The room was lengthened and widened in successive 10-ft increments until it measured 80 by 200 ft. Periods up to 14 months were allowed between changes to check roof sag. Five years after the test room was first opened and 3 months after the final lengthening to 200 ft, an 18-in. layer of roofstone fell along a fractured zone in about the center of the room. Approximately three-sevenths of the roof area was affected. After an additional four years the remainder of the roof is still standing. The test instruments were removed before the roof fall, and no further measurements have been made.

As a result of the rock falls in the test room, diamond drillholes were placed in the mine roofstone at selected intervals. Periodic examination of the walls of these holes with a borescope showed an increasing number of partings at 12-in. depths in certain areas of the mine. In 1953 a rock fall occurred near the lower portal in an area that had been exposed to weathering for more than five years. As limited working space does not permit abandoning the older underground areas, which are used for experimental work, it was decided that the mine should be roof-bolted to prevent further rock falls. With the technical advice of the USBM Roof Control Section, a series of pull tests was made with a wedge-type roof bolt, and satisfactory results were obtained. A 1-in. diam iron bolt was adopted, which, installed under a torque of 300 ft-lb, failed at 24,000 psi. Approximately 4200 roof bolts have been installed to date.

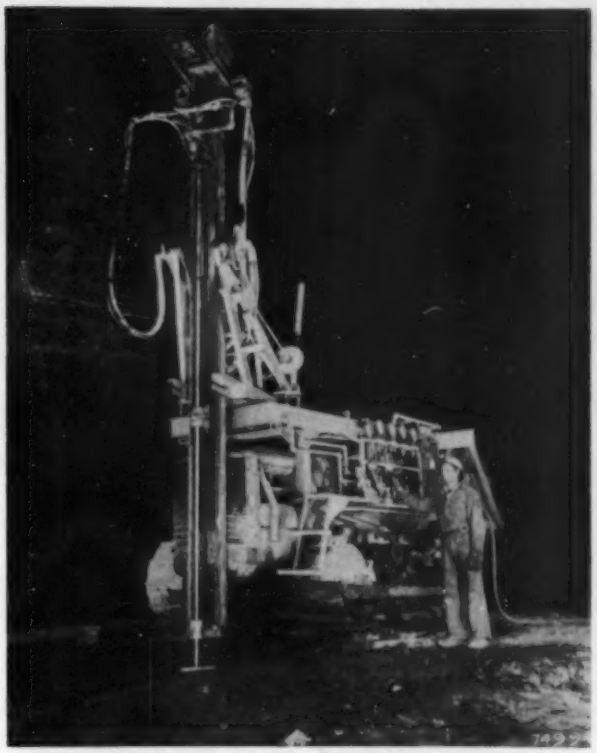
Rotary Drilling

The cost of drilling blastholes obviously represented a large percentage of overall mining expense. Accordingly, much of the research has covered drilling. Early work was devoted to percussion drilling, which is still standard practice in the present headings; however, because of certain inherent disadvantages of percussion drilling, experiments on rotary drilling were begun in 1948 and have continued to date.

Fishtail auger bits used in coal mining were first tried without success. Two-prong coal augers with tungsten carbide inserts were then tested with some success in medium grade shale. During the preliminary experiments, two constant-speed electric coal drills with screw-type feedbars were used for testing the bits. One of these, a 7½-hp coal drill with a feed rate of 36 in. per min, worked well when rich shale was being drilled. In lean shale, however, inability to control the feed rate was a definite disadvantage and resulted in broken bits and augers.

The next test drill was a 2-in. air drill mounted on a wagon drill slide, which had a chain feed driven by an air motor. The feed pressure or thrust could therefore be controlled independently of the drill motor. The air drill was rated at 300 rpm but actually operated at 100 to 300 rpm, depending on drilling conditions. Diamond drill rods of EX size were used, and waterholes were drilled in the test bits to permit use of water to clear the cuttings.

Many different types of bits were tested on this unit. The most satisfactory were masonry-type bits with tungsten carbide inserts. Drilling rates up to 75 in. per min and total penetrations, before bit failure, up to 300 ft were attained with bits that had been specially designed for drilling oil shale. Certain characteristics were observed for all the bits.



Drilling vertical hole with test drill located on the upper bench. This machine was built to USBM specifications for conducting drilling research. Equipment is so designed to give complete control of torque, thrust, and revolutions of the drill rod.

Those with the harder grades of tungsten carbide did not require frequent sharpening, but all failed because the insert chipped or cracked long before the bit was worn out. The bits with the softer grades of tungsten carbide did not chip as readily, and some lasted until completely worn out, but they required resharpening every 15 to 25 ft.

Throughout all these tests the operating conditions were fixed by the drill unit and could not be varied appreciably. It was felt that several bits tested might have performed much more satisfactorily under other operating conditions, such as higher rpm, higher thrust, or both. It was obvious that to give the bits a fair test and to determine optimum drilling conditions an adequate test drill would have to be obtained. With such a drill it would be possible to vary and measure accurately the operating conditions independently of each other. No such drill was on the market. Before it was decided that the USBM should build such a machine, the possible advantages of rotary drilling for oil shale mining were carefully analyzed:

1) Because of a drilling rate of 60 in. or more per min compared to 20 in. per min with percussion drills, the cost of drilling labor per foot of hole could be reduced at least 50 pct.

2) Because drilling efficiency and penetration rate of rotary drills do not decrease in long holes as they do with percussion drills, rounds more than double the present depth could be drilled on the top heading of the mine. This would increase shovel efficiency, reduce the cost per ton of scaling loose rock from working faces preparatory to drilling, and decrease the time required for power loading one half.

3) Power consumption would be reduced because electric power could be used directly or through a

more efficient hydraulic system rather than through an inefficient compressed air system.

4) The cost per foot of hole for drill rod replacement would be negligible. The present cost of drill rods for percussion drilling is 2¢ per ft of hole drilled.

5) Most of the drilling noise would be eliminated, improving working conditions and comfort.

6) Capital costs for drilling equipment and initial mine-development requirements would also be reduced. Less than half as many rotary drill jumbos as percussion drill jumbos would be required to produce a given tonnage.

Because of these and other possible advantages of rotary drilling, it was decided that the USBM should build its own rotary test drill.

To have a test drill that could operate under wide limits of thrust, rpm, and torque, it was decided that the equipment should be completely hydraulic. An available tractor was selected upon which the drill unit would be mounted, and the unit was designed incorporating the various features desired. A primary consideration influencing the design was that a research rather than a production tool was to be built.

Specifications for the hydraulic equipment and system were drawn up and submitted to several companies for bid. The contract was awarded to TEC Engineering Corp., which made the lowest bid on satisfactory equipment. The drill unit was mounted and assembled by the Winter-Weiss Co. from the USBM design.

The completed test drill consists of a hydraulic drill motor mounted on a 16-ft feed carriage. The drill motor can develop a maximum torque of 2000 in.-lb and can be controlled between 0 and 1050 rpm. It has a hollow drive shaft and water swivel for wet drilling. The drill motor is mounted on a slide or carriage attached to an endless chain. This chain is driven by a hydraulic feed motor and can deliver a maximum thrust of 3400 lb to the drill motor. Both thrust and torque can be preset to any desired value below their maximum limits. A 50-hp, 400-v electric motor operates the hydraulic pumps that drive the motors. The complete assembly is mounted on a model HD-10 tractor.

As soon as the experimental rotary drill was placed in operation, several types of bits tested with the previous air drill were tried on the new one. Performance of these bits was materially improved. Of particular importance was the fact that those bits with the harder grades of tungsten carbide, which chipped and cracked when tested with the air drill, did not fail when tested with the new hydraulic drill. This was apparently due to the fact that the hydraulic drill operates very smoothly and eliminates most of the shock and impact stresses induced when an air drill is used. Recent experimentation has therefore been concentrated on bits having harder and more wear-resistant grades of tungsten carbide.

In general, it has been found that for best drilling life, low rpm at high thrust is most effective. Highest drilling rates require high rpm and thrust.

Blasting experiments have indicated that 1⅝-in. diam blastholes are preferable to 2-in. holes for breaking bench rounds. Therefore, the smaller diameter holes probably would be used in a commercial operation. In recent experiments 1⅝-in. rotary bits were tested by drilling vertical down holes through the 34-ft bench. The performance of a 1⅝-in. diam bit tested at 2500 lb thrust and at various spindle speeds is shown in Table I.

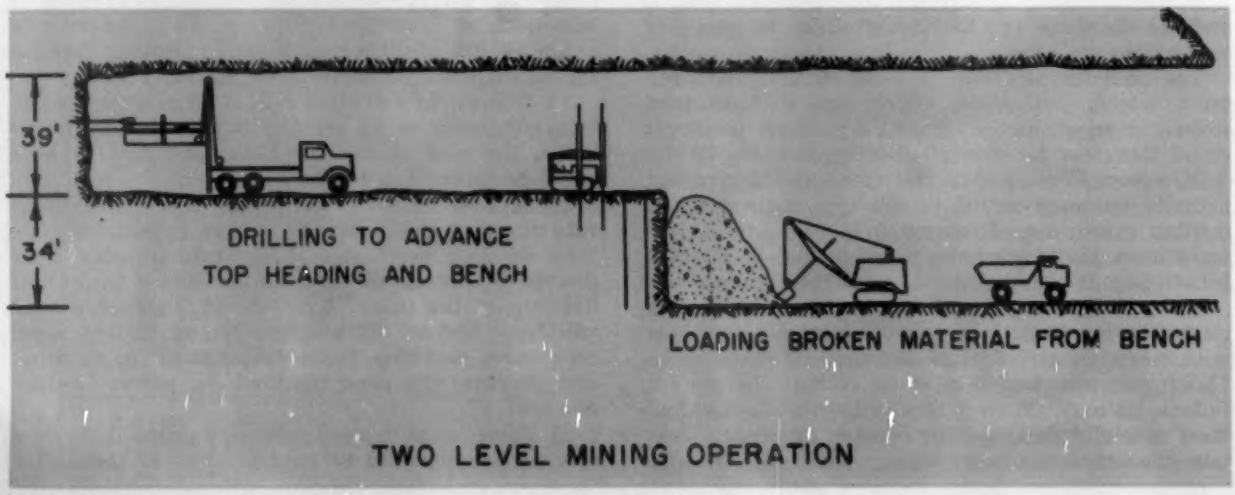
A bit of similar design drilled more than 1000 ft under constant test conditions of 400 rpm and 2000 lb thrust before it required resharpening. After sharpening, this bit drilled an additional 994.5 ft of vertical hole and 215.8 ft of horizontal hole before the next sharpening. Average penetration rate was 47.4 in. per min.

It is estimated that bits of this type would average four sharpenings apiece and that the total footage drilled per bit would be 5000 ft or more. The rotary bits cost $40 apiece because they were made especially for test purposes. Their cost when purchased in large quantities for commercial use is not definitely known, but is estimated at about $20 apiece. The cost of four sharpenings is estimated at $5 per bit or $1.25 per sharpening. The cost of rotary drill rod replacement is negligible. There has been no drill rod breakage to date.

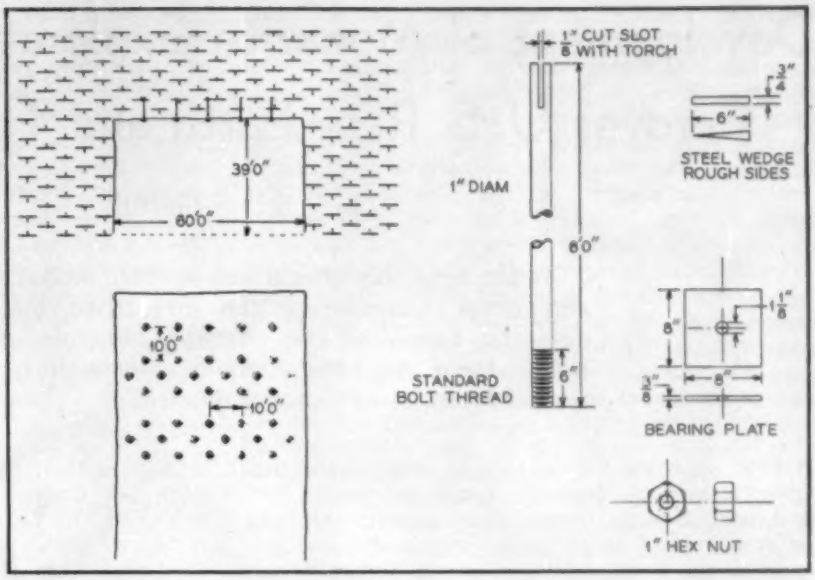
The cost of rotary drilling would be 0.5¢ per ft for bits and drill rod as compared to 2.8¢ per ft with percussion drilling.

Table I. Performance Characteristics of a 1⅝-in. Rotary Test Bit

Spindle Speed, Rpm	Thrust, Lb	Torque, In.-Lb	Drilling Hp	Average Penetration Rate, In. per Min.
400	2500	600 to 750	4.9	56.3
700	2500	750 to 900	7.3	104.6



TWO LEVEL MINING OPERATION



Details of roof bolt installation and roof bolts at the oil shale experimental mine. Tests performed on bolts placed with 300 ft-lb torque indicated that tension could go as high as 24,000 psi before failure. Several thousand roof bolts have been used.

Table II. Cost Comparison of Percussion and Rotary Drilling in Oil Shale Mining*

	Percussion	Rotary
Mine output:		
Tons per day	19,200	28,000
Tons per man-day, total	65	128
Manpower per day	298	218
Equipment investment:		
Total dollars	2,500,000	2,350,000
$ per ton-day	130	84
Direct operating cost:		
Supplies and material, $ per day	3,812	4,447
Labor, $ per day**	4,284	3,122
Depreciation of equipment, $ per day	855	805
Total, $ per day	8,951	8,374
Total, $ per ton	0.466	0.299

* A production test run in 1949 using essentially the same equipment and methods as proposed for the 19,200 tpd operation lasted four weeks. The upper heading was mined for two weeks, producing 16,910 tons. The equipment was moved to a middle bench for two weeks and another 15,650 tons was produced. Accurate cost figures showed a direct cost of $0.292 per ton based on 1949 prices.
** Based on 1954-55 wage scales. The average wage for percussion drilling is $13.01 and for rotary drilling, $13.12. The difference is due to the types of labor required.

Thus rotary drilling for the benches is definitely cheaper than percussion drilling on the basis of drill steel and bits alone, not including other factors such as reduction of cost of drilling labor by one half to two thirds and lower power consumption.

The experimental rotary drill has given very good service during the time it has been in operation. Because of its flexibility it has been ideal for testing rotary bits. Although it was not designed for a production unit, many of its features would be incorporated in a production drill jumbo.

Only limited testing has been done on the drilling of headings by rotary methods. A rotary-drill heading jumbo was designed and is now under construction. When construction of the heading jumbo is completed, an experimental program will be followed on long-hole drill rounds. A horizontal test hole 52.5 ft long was drilled to determine bit deviation. Surveying of the collar and breakthrough point of the drillhole showed a horizontal deflection of 0.12 ft and a vertical deflection of 3.04 ft. Vertical deflection is attributed to drill-carriage tilting, with the thrust on the drill rods. This condition has been corrected in the design of the heading jumbo now being built. It is fairly definite that a method of horizontal rotary drilling will be developed having the same advantages as those accompanying vertical rotary drilling.

A USBM Information Circular on rotary bit development and design for drilling oil shale is being written by the Oil-Shale Mine Branch.

Estimated costs and mine output for two-level commercial mining operations, one using percussion and the other rotary-drilling methods, are summarized in Table II. Although the estimates are based on different mine output, the costs are still comparable. This table shows that the total tons per man-day for the mine using rotary drilling is almost twice that for percussion drilling, while the manpower required in the rotary-drilled mine is 218 against 298 in the percussion drilling. Total equipment investment is 6 pct less for rotary drilling but 35 pct less on the dollar-per-ton-day basis. Total direct operating cost, in dollars per ton of shale mined, is decreased just over 40 pct by the use of rotary instead of percussion drilling. As mentioned, this decrease in operating cost is due largely to higher drilling rates, lower manpower requirements, and much longer bit and drill rod life.

Blasting Research

Experiments have been conducted on many phases of blasting in a continuing effort to reduce the cost of breaking rock. The effectiveness of various grades of explosives was compared, and many different drillhole patterns were tried in both heading and bench rounds. Experiments were conducted to determine the maximum effective burden for blastholes of various diameters. High speed motion picture studies were made of blasts, and the time required for the initial movement of rock after detonation was measured. Experiments were made to compare the effectiveness of millisecond-delay and standard-delay electric blasting caps.

Research testing of long-hole blast rounds is planned.

Development of Monazite Exploration Techniques Improves U. S. Rare Earth and Thorium Supply

by Robert F. Griffith

At the time this article was written, monazite was the star actor. Considering the intensified interest in a domestic supply of the titanium minerals, particularly rutile, these methods apply equally well to obtaining samples from stream placer deposits.

IN 1948 when the U.S. Bureau of Mines began the investigation of domestic monazite placers for the Atomic Energy Commission, deposits of this type amenable to large-scale operations were unknown in the U. S. Intensive search for such deposits had not been carried out in the past. Problems to be met included scarcity of men with placer experience and need for development of new exploration, evaluation, and analytical procedures. As a result of the exploration program three dredges have gone into operation in one area in Idaho and another dredge is operating in South Carolina.

Search for Deposits

In the search for areas to be investigated for monazite, the first step was a thorough study of all available literature reporting occurrences of the mineral. Initial work was guided largely by many reconnaissance reports prepared by the U. S. Geological Survey and the AEC. As the work progressed many new deposits, not mentioned in the literature, were called to the attention of USBM engineers by prospectors who had noted the presence of the yellow, heavy sand while prospecting for placer gold. Every prospector was given an attentive ear.

Greatest success to date has resulted from investigation of areas previously unreported in the literature. The Big Creek deposit in the Long Valley area of Valley County, Idaho, largest producer of monazite in the U. S. to date, was discovered as a direct result of a tip given by an old prospector to a USBM engineer. Before this deposit was visited by the prospector and the engineer in the fall of 1949, no monazite had ever been reported as occurring in this area. Again, in the Southeast the most attractive deposits from an economic viewpoint were found 70 miles from previously reported and worked occurrences in the monazite belt. These deposits were called to the attention of a USBM engineer by a western dredge operator who was reconnoitering the Southeast for workable gravel deposits. Benefits derived from the application of sound geologic principles to exploration programs are well established. It is equally important, however, that knowledge obtained by mining operators and prospectors from years of practical experience should not be overlooked.

At the time this heavy sand investigation was initiated, placer mining was rapidly becoming a lost art. A few gold dredges were operating in the western states, but workable gold placer gravels were fast becoming depleted. As a result, mining engineers and technicians with practical placer experience were relatively scarce compared with hard-rock men. It was therefore necessary to train men for the reconnaissance parties, the drill and sampling crew, and the field gravity-concentration laboratories. Even the apparently simple operation of correct manipulation of a gold pan was difficult for some to master. Perhaps good placer men are born, not made. This new interest in heavy mineral sands was like a shot in the arm for the placer miners, and soon well trained crews were busily searching for the elusive mineral monazite.

R. F. GRIFFITH, formerly with the U. S. Bureau of Mines, is now Superintendent of Marine Minerals Inc., Aiken, S. C.

Exploration and Evaluation

Preliminary Examinations: The investigation of a favorable area begins with panning of gravel taken from promising spots such as the surfaces of gravel bars that have small pebbles exposed on the inside (short side) of stream beds. A surface concentration is generally found at such places owing to the action of the stream which, in flowing over a bar, carries the light minerals downstream and leaves the heavy minerals among the pebbles acting as riffles. Experience had shown that if monazite is not found at such selected spots in sufficient quantity to be of interest, it will not be found in interesting quantity at depth. A rough rule of thumb that has been developed and verified by exploitation of deposits in many areas is to divide by four the number of pounds of monazite in a cubic yard of bar gravel, to obtain a basis for estimating the total monazite content of a deposit.

Concentrate from panning is examined in the field with a 40X pocket microscope known as the Penscope, and the percentage of monazite present is estimated. A determination has been made that 1 teaspoonful of monazite obtained from a level 16-in. pan of gravel is equivalent to 2½ lb of monazite per cu yd.

The tenor of a placer deposit required to support profitable exploitation depends on many factors. A deposit from which 1 lb of monazite per cu yd can be recovered may be dredged successfully under present economic conditions, provided that all other conditions are ideal for dredging. On the other hand, if a placer can be worked only by hand methods, it must contain 15 lb or more of monazite per cu yd to be of interest. Obviously, a number of other mining methods that lie between these two extremes are available. Important factors are the quantity and specie of accessory minerals contained in the concentrate. A deposit may contain

enough monazite to appear attractive, but the cost of separating a small percentage of monazite from a large bulk of nonmarketable heavy minerals may be prohibitive. In other instances, the accessory minerals may make an otherwise marginal deposit attractive. For example, a few cents worth of gold recovered with the monazite would pay part of the operating expense, and a ready market for accessory minerals such as ilmenite, rutile, zircon, and garnet could mean the difference between success and failure. The quantity of +¼-in. material is an important factor in the Southeast, where a ready market exists for gravel. In general, dredging ground that contains 20¢ to 25¢ per cu yd, f.o.b. railhead, in marketable minerals and materials would be considered worthy of investigation.

If the quantity of monazite in the concentrate obtained by panning is sufficient to be of interest, several 80 to 100-lb grab samples are taken of the gravel and subsequently concentrated and evaluated in the field laboratory. A preliminary report, which incorporates the field laboratory results with all factors related to possible mining operations, is then prepared by the examining engineer. These reports are reviewed carefully, and plans are prepared for extensive sampling of the promising deposits by one or more of several methods, usually churn drilling.

Sampling Techniques: Modified churn drilling techniques have proved to be the best all-around method for accurate sampling of monazite placer deposits. Holes can be completed to bedrock and samples obtained from nearly all types of placer deposits. Where the material sampled is composed predominantly of fine sand, such as the beach and ancient shoreline deposits of the Southeast, jet-drilling techniques have proved applicable. Auger drills are useful in determining the stratigraphic sequence and the depth to bedrock, but methods have not been developed for obtaining accurate samples. Bulldozer trenching and shafting with telescoping steel caissons have been used in special cases. Water conditions, however, generally preclude the adaptation of these methods. A few shafts may be sunk around churn drillholes as a check on the accuracy of the churn drilling. The advantages of shafting over drilling are the greater volume of sample obtained and the truer picture gained of the character of material penetrated. Disadvantages are the high cost and the difficulty, and often inability, of completing holes to bedrock.

Churn drilling of deposits by the USBM is generally done under contract. Standard truck-mounted churn drills, 6-in. casing, and 7½-in. drive shoes are employed. Standard drilling patterns are used, except that the holes are widely spaced. Drilling done by the USBM was not closely spaced or development drilling; the purpose was not to block out reserves or to prove ground but rather to indicate the more promising areas for private industry to develop. Indicated reserves only are reported. Several modifications of standard drilling procedures were developed for the drilling and evaluation of monazite placer deposits. The usual drive interval in sampling gold-bearing gravels is 1 ft. However, in sampling for monazite, the greater bulk and more even distribution justifies a larger sample interval. A 2½-ft drive before bailing is about the maximum that can be made before friction inside casing prohibits further rise of core. The bailer contents from two drives are combined into one 5-ft sample unless unusual changes in stratigraphy make this interval inadvisable. As in gold sampling, part of each sample is panned and its mineral content estimated at the drill site for the purpose of logging the hole and controlling the depth of drilling. The material panned is returned to the original sample. The samples are dried in pans over an open fire in the field and screened −¼-in. The oversize is weighed, examined, and discarded; the undersize is weighed and sacked for treatment in the field laboratory. All calculations are based on dry weight recovery, and tests are made to obtain the factor to convert from weight to volume. This procedure is perhaps the widest divergence from standard gold placer evaluation techniques where calculations are based on theoretical volume of the core and core rise modified by the application of factors such as the Keystone constant to compensate for discrepancies.

In basing calculations on weight recovery the assumption is made that the material representing the difference between theoretical recovery and actual recovery is similar in all respects to the material recovered. Many discussions have ensued as a result of this practice; however, the answer is that check shafts and dredging operations have proved the accuracy of this method. It should be noted that the weight recovery method would not be applicable to placer material composed largely of cobbles and boulders. Because of the use of the thin placer bit, the main purpose of which is mixing, many cobbles are not broken and are pushed to one side by the drive shoe. The bailer captures the original fine material, which contains the monazite, in preference to the coarser particles so that calculations based on weight recovery would result in high values. The monazite deposits that have been investigated to date and are being exploited are composed largely of fine-grained material, −1 in.

Michigan model 75-A tractor-shovel assists in cleanup work at Marine Minerals Inc. titanium dredging operations near Augusta, Ga. The 6-cu ft bucket line dredge was built and remodeled by Yuba Mfg. Co. for the recovery of rutile, ilmenite, zircon, and monazite. This dredge was moved to its present location from Montana where it was used to recover gold and sapphires from a deposit on the Missouri River.

Therefore, the method has proved applicable. In one area accurate volume measurements were made of check shafts sunk around churn drillholes, and the entire material from the shafts was concentrated. The comparative results follow:

Site	Lb per cu yd	
	Concentrates	Monazite
Drillhole 1	26.3	1.9
Shaft around drillhole 1	24.2	2.0
Drillhole 2	25.6	2.2
Shaft around drillhole 2	25.2	2.5

To convert from weight to volume, it has been determined that for deposits that contain only a small percentage of +1-in. material the dry weight of material in place is very close to 100 lb per cu ft.

Field Laboratory Methods: The −¼-in. material received at the field laboratory from the drilling operations is screened —16-mesh and concentrated on Wilfley tables fed by hydraulic cone classifiers. The +16-mesh material is checked with a Geiger counter, and if radioactivity is detected this material is treated on a laboratory jig. Radioactivity in the +16-mesh fraction is generally caused by black, opaque radioactive minerals. In all fields investigated to date, more than 99 pct of the monazite has occurred in the —16-mesh fraction.

The final concentrate from the Wilfley tables, which contains from 85 to 95 pct heavy minerals, is dried, weighed, and computed in pounds of black sand per cubic yard of gravel. Any appreciable gold contained in the samples is amalgamated, parted, weighed, and computed in cents per cubic yard. Field estimates are made of the mineral content of each final concentrate to facilitate rapid field control. The concentrate is mixed on a rolling cloth, a 10-g sample taken, and the magnetite removed with a hand magnet, weighed, and computed. The remainder of the sample is examined with a microscope and the percentage of ilmenite, rutile, garnet, zircon, and monazite estimated visually. Zircon content is additionally estimated with the use of a Mineralight; the fluorescence of zircon is a beautiful golden yellow under shortwave ultraviolet light. The monazite content of the concentrates is also estimated by radiometric method developed by the USBM field laboratory at Boise, Idaho. The radioactivity of the sample is compared with that of pure monazite standards of the same weight. If the monazite standard is from the same field as the unknown sample, and if the sample contains no radioactive minerals other than monazite, the results can be interpreted directly in terms of percent monazite and thus in pounds of monazite per cubic yard of gravel. If the standard and the sample are from different fields, the relative radioactivity of the monazites can be computed and applied to the final calculations from chemical ThO_2 and U_3O_8 analyses of both monazites. If other radioactive minerals are present, the radiometric results can be reported only in terms of equivalent monazite.

In one particular area where 23 holes were drilled, results obtained by application of the above-described field methods indicated 1.10 lb of monazite per cu yd of gravel; final results based on precise analytical work indicated 1.13 lb of monazite per cu yd. Examination of the heavy sands by the field crews is solely a control measure to provide a basis for directing the course of a drilling program. Although results obtained by field techniques are often remarkably accurate, the final evaluation of an area depends on more precise analytical procedures.

Analyses

Early in the program it was discovered that unless the mineralogy of the black sands is well established not only field estimates but even radiometric and chemical analyses may be misleading. Authors of some early reconnaissance reports were badly misled as to the monazite content of certain areas when they depended upon radiometric and chemical analyses. For example, samples submitted from the Waterford field in California proved to be not the simple black sand concentrate containing only monazite that the early investigators supposed. About 90 pct of the radioactivity of the samples was due to uranothorite. Later, when Idaho sands were explored, samarskite, euxenite, fergusonite, and brannerite were encountered and complicated the investigation. For this reason the USBM developed and adopted the triple-check method of analysis: radiometric, chemical, and mineralogic.[1] One of the most difficult problems in establishing this triple-check method was development of a rapid analytical method for determining the thorium content of black-sand concentrates. After many months of testing various chemical reagents, a procedure was developed that provided high accuracy and yet was simple enough to permit as many as six analyses per manshift.[2]

Conclusion

By these methods substantial reserves of monazite have been found in the last four years to insure domestic production of this mineral. For the first time in the history of the U. S., the rare earths industry need not depend entirely upon foreign sources of supply.

As a result of these investigations, three dredges were put in operation in one area in Idaho, with ample reserves to continue operations for many years. It is also gratifying to report that the ground being dredged in Idaho actually carries the quantity of monazite predicted by the above evaluation methods. A dredging operation in South Carolina is recovering rutile and ilmenite with monazite and zircon as byproducts. Shipments from this location are scheduled to start in November 1955 when the dry mill for separating the heavy minerals will be complete.

The USBM's work was not completed with the exploration phase. In cooperation with operators of this infant industry, dredges and separation plants were systematically sampled and studied to improve recoveries. As a result, monazite recovery on the dredges was increased from 60 to nearly 90 pct and in the separation plant from 75 to 96 pct.

Indications are that the country's consumption of the rare earth metals and thorium may increase considerably in the next decade. At least, the U. S. no longer depends completely on foreign sources of supply, and belief seems warranted that adequate reserves of monazite will ultimately be discovered to meet the nation's requirements.

References

[1] Mitchell H. Kline: Evaluation of Monazite Deposits, U. S. Bureau of Mines, RMO-908. Prepared by the Bureau of Mines for U. S. Atomic Energy Commission. Technical Information Service, Oak Ridge, Tenn., April 1952, 16 pp.

[2] R. Kronstadt and Allan R. Eberle: Analytical Procedure for the Determination of Thorium, U. S. Atomic Energy Commission, RMO-838. Technical Information Service, Oak Ridge, Tenn., January 1952, 9 pp.

A Survey of Exploration Drills

Flexibility is the keynote in designing modern exploration drills—that and mobility. Add to the flexibility of individual drills the wide range of models, and the man looking for a drill has ample choice today.

Weight? Choose from models as light as 50 lb or as heavy as 10,000 lb. **Hole capacity?** From less than 1 in. for smallest core drills to 20 in. or more for auger types. **Transportation?** The lightest go by packsack (in fact, that is one trade name); others are designed to go by Jeep, truck, on skids or are built on light trailers. **Power?** Select air power, gasoline or diesel engine, electric motor, or use a power takeoff from the vehicle on which the drill is mounted.

Drill bits offer almost as much variety as the drilling machines themselves. Many drills are suitable for a variety of uses, and often adapt to several types of bits with ease. Some of the types available are: diamond core, diamond reaming, rotary, auger, shot, and special soil sampling tools.

Presented here is a sampling of light and medium weight drills especially adaptable for exploration and testing. Two ultra-light and portable units are described at the bottom of the page, and a more complete listing of this type was given in the ME Notebook in the July 1955 issue.

Air operated and post mounted types designed for use underground are not covered in these pages, but some of the manufacturers of this type of drill are listed in the table on page 935. No claim is made that this list is complete—it is a sampling to suggest the drill type that might meet a given set of drilling and transportation requirements.

(Continued on page 934, table on page 935)

This Acker model AP in use by the Michigan State Highway Dept. is typical of flexibility and variety of modern field drilling equipment. Unit comes with engine or with power takeoff; is built in two sizes; may be skid, Jeep, or truck mounted; and adapts to core, auger, or blasthole drilling.

Two Ultra-Portable Drills

Bosch-Homelite Rock Drill: Power is supplied from a lightweight Homelite generator to the electric driven drill. The same generator powers a high pressure blower. Air from the blower is used in the hole and also operates the airleg. The generator can also be used for standard power tools and lights.

Packsack Diamond Drill: An improved model of this drill supersedes the one listed in the July ME Notebook. Specifications are given below. The new model 3-M has more power, less weight, drills deeper, and has a wide range of attachments. Pumps, saws, grinder, auger, and 110-v generator may be driven by the unit.

Roundup of Portable Exploration Drills†

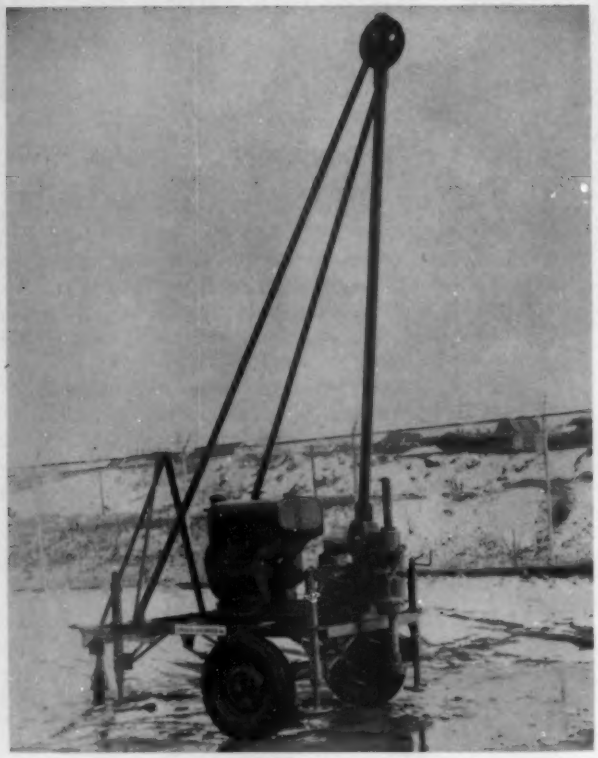
Drill	Type	Power, hp	Depth, ft and Hole Size, in.	Weight, lb	Cost of Drill, $*	Manufacturer or Distributor
Packsack	Diamond Core	5 Gas	100 1¼	Drill 32 Pump 48	850 (complete)	Packsack Diamond Drills Ltd.
Bosch-Homelite	Rock Drill	—	—	Drill 65**	—	Homelite Corp.

* Cost approximate, believed correct at time of publication.
** Weight of separate generator not given.

† See listing given in July 1955 MINING ENGINEERING, page 644.

Mobile Drilling Units

Core Drilling — Soil Sampling



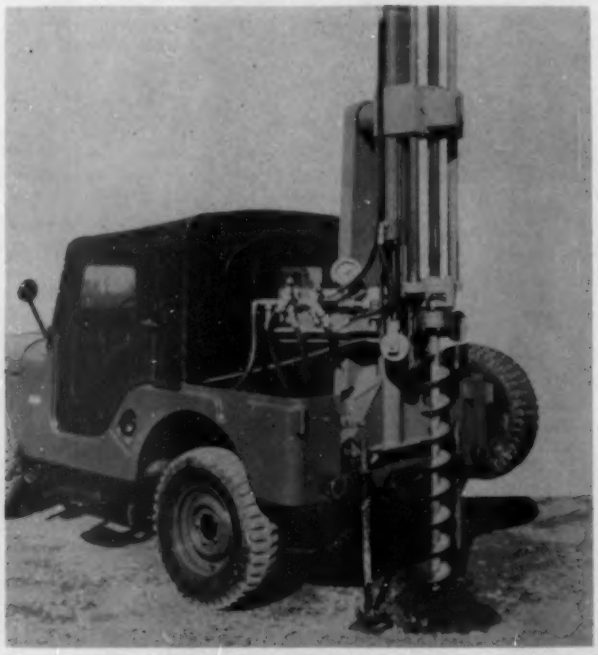
ABOVE: The Gustafson Drill Scout uses idea of trailer mount to be hitched to back of Jeep or truck. RIGHT: Sprague & Henwood has come up with this trailer mount for the model 30 drill.

Mounting light and intermediate weight core drills and soil sampling units on trailers is gaining popularity. One major advantage is that easy portability is retained without tying up a truck permanently. Stability is provided for with a set of screw type leveling jacks.

Trailer mounted units offer greater portability than skid mounted drills but cannot use vehicle power takeoff, as is the case with some of the other mobile rigs. Many manufacturers offer options so that basic skid mounted unit may be placed on truck bed or on special trailer.

The two trailer type drills shown above weigh between 1000 and 1500 lb. One has a maximum capacity of 300 ft of NX hole or 600 ft of EX hole, although the manufacturer does not recommend use of single pole derrick for lifts greater than 200 ft. The other drill is rated to 200 ft. See table opposite.

(Continued on page 936)



LEFT: The Toledo earth drill shown mounted on a Jeep was developed by Toledo Testing Laboratory for both soil sampling and core drilling jobs. Now manufactured by Continental Equipment Sales Inc., drill may be mounted on 2-wheel trailer or on truck as shown. For road travel the drill is moved hydraulically onto the bed for better balance. Power is supplied by vehicle takeoff. RIGHT: These two Acker drills show variety of designs available. Other mounts possible are trailer, skids, or truck; while power supply may be air motor, electric motor, gasoline or diesel engine, or from vehicle takeoff.

Specifications of Typical Exploration Drills

Model	Type	Mounting*	Power, hp**	Depth, ft	Weight, lb***	Manufacturer
			Trailer Mounted Units			
LD	Core	Tr, T, S	G, D, A, E, PTO 7½ to 16	EX-400 NX-250	1050 to 1975	Acker Drill Co.
No. 30	Core	T, Tr, S	G, D, E, A	EX-600 NX-300	1350[1]	Sprague & Henwood Inc.
Drill Scout	Core or Rotary	Tr	G 6 to 9	200	1000	Gustafson Mfg. Co.
			Lighter Skid Mounted and Mobile Drills			
Holeycat	Core	T, J	G	300	400	Atomic Engineering Corp.
Toledo	Core or Auger	T, J	G, PTO	300	——	Continental Eqpt. Sales Inc.
AP[2]	Auger	T, S, J	G, PTO 33	75 for 6-in.	1150 to 1750	Acker Drill Co.
Teredo	Core	Tr, T, S, J	G, D, E, A, PTO 16	EX-600 NX-300	1290 to 1340	Acker Drill Co.
BBS-1[3]	Core	S	G, D, A 24 to 30	EX-1200 NX-500	1145 to 2245	Boyles Bros. Drilling Co. Ltd.
No. 8	Core	S	G, D, E, A 25	EX-1250 NX-650	1290 to 2640	Chicago Pneumatic Tool Co.
Prospector	Core	Tr, S, J	G, E 6	EX-300	590 to 795	E. J. Longyear Co.
24	Core	S, J, Tr	G	EX-700	1000	E. J. Longyear Co.
No. 7	Core	S	G, E 14	EX-500	1300	Joy Mfg. Co.
No. 12B	Core	S	G, A, E 20	EX-1250 NX-650	960 to 1230	Joy Mfg. Co.
L-2	Core	S	G, D, E, A	EX-500	1400	Sprague & Henwood Inc.
40-C	Core	S	G, D, E, A	EX-1000 NX-500	——	Sprague & Henwood Inc.
			Intermediate Weight Drills			
BBS-2[3]	Core	S	G, D, A 70	EX-2400 NX-1400	2200 to 3380	Boyles Bros. Drilling Co. Ltd.
No. 15	Core	S	G, D, A, E 25 to 45	EX-2250 NX-1150	1545 to 2815	Chicago Pneumatic Tool Co.
Junior Straitline	Core	Tr, T, S, J	G, D, E, A 25	EX-1250 NX-225	1725 to 2710	E. J. Longyear Co.
22-HD	Core	S	G, D, E, A 30	EX-2000 NX-1000	2100 to 2700	Joy Mfg. Co.
142	Core	S	G, D, E, A	EX-2000 NX-1000	——	Sprague & Henwood Inc.
			Heavy Duty Drills			
BBS-4	Core or Rotary	S	D 100	BX-5000 NX-4000	10,700 to 11,100	Boyles Bros. Drilling Co. Ltd.
44	Core	T, S	G, D 44 to 63	AX-4000 NX-2400	4075 to 4650	E. J. Longyear Co.
AR-1250	Core or Rotary	T	PTO	1500 for 2⅜ pipe	9250[4]	Drilling Accessory & Mfg. Co.

* Mounting—J, Jeep; T, truck; Tr, trailer; S, skid. ** Given for gasoline engine where applicable—G, gasoline; D, diesel; E, electric; A, air motor; PTO, power takeoff. ***Weight varies widely due to range of mounting, power, and head. Lightest drills are electric or air drive, heaviest are diesel. NOTES: 1. Weight is for skid mount with single pole derrick. 2. Two models available, lighter one uses vehicle power takeoff. 3. Lighter model available. 4. Weight is for complete drilling unit less truck. Vehicle specified is International R-160, R-170 or equivalent.

Classification is arbitrary, based primarily on the weight of the basic model skid mounted and with gasoline engine power option. Some manufacturers build both medium and heavy duty version of same model.

Addresses of Manufacturers Mentioned

Acker Drill Co.
Scranton 3, Pa.
Atomic Engineering Corp.
230 Pitkin St., Grand Junction, Colo.
Boyles Bros. Drilling Co. Ltd.
Vancouver, B. C.
Chicago Pneumatic Tool Co.
6 East 44th St., New York 17, N. Y.
Continental Eqpt. Sales Inc.
1810 North 12th St., Toledo, Ohio
Demo Tool Corp.*
8735 Melrose Ave., Los Angeles, Calif.
Diamond Drill Contracting Co.*
South 18 Stone St., Spokane, Wash.
Drilling Accessory & Mfg. Co.
2006 South Industrial Blvd., Dallas, Texas
E. J. Longyear Co.
1700 Foshay Tower, Minneapolis 2, Minn.
Gustafson Mfg. Co.
Corpus Christi, Texas
Homelite Corp.*
624 South Anderson St., Los Angeles, Calif.
Joy Mfg. Co.
Oliver Bldg. Pittsburgh 22, Pa.
Packsack Diamond Drills Ltd.*
1385 Hammond St., North Bay, Ont.
Pitman Industrial Products Co.*
608 Fifth Ave., New York 20, N. Y.
Sprague & Henwood Inc.
Scranton 2, Pa.
Stance Mfg. & Sales Inc.
1931 Pontius St., Los Angeles 25, Calif.
Warsop Power Tools Ltd.*
42 Northline Road, Toronto, Ont.

* See listing of Ultra-Portable Drills in ME Notebook, July 1955, and on page 933 this issue.

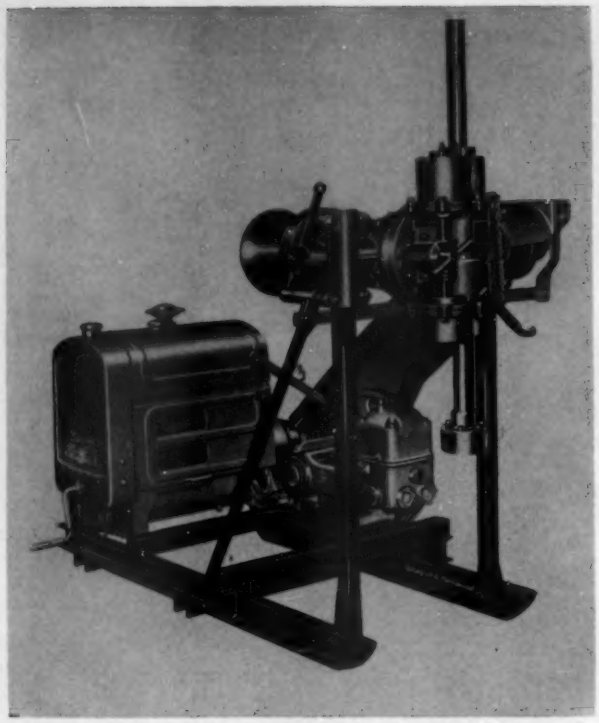
Light and Medium Drills

Truck or Skid Mounts Are Used

Machines in this class range from 1000 to 3000 lb in weight, and the weight of a given model will depend on the power supply. For instance, several hundred lb less weight is result of choosing electric instead of gasoline power. Diesel engine is heaviest power supply. Lightest version of given model is usually the air operated type.

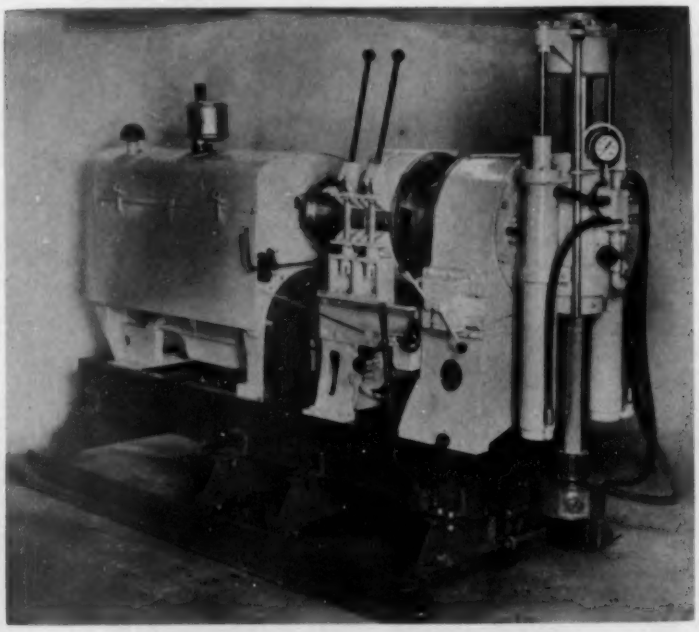
Capacity shows about the same range as the weight. Smaller drills handle up to 200 or 300 ft of NX hole while they go to 400 to 600 ft with E rod. Heavy duty machines in this size class will handle up to 1200 ft of N and over 2000 ft of E rod when equipped with largest power option.

Typical specifications for a drill in the middle of the range are: capacity, 1250 ft EX coring, to 650 ft NX coring; weight with 25-hp gasoline engine, 1600 to 1900 lb; length of feed, 18 in.; choice of hydraulic or screw feed; and overall size, 7x3x4½ ft high.



Sprague & Henwood model L-2 is designated "light weight for shallow hole drilling," by builder. The 1400-lb machine is rated to 500 ft of EX hole, or 400 ft with AX size.

Heavy Duty Rotary and Core Drills



The big exploration rigs get into the 10,000-lb class. Machines are capable of drilling to as much as 5000 ft, and portability becomes a more comparative term, unless the rig is truck mounted. On the other hand, these machines are capable of making large diameter and deep holes—fast.

Longyear's Model 44: Shown at left above is this new drill introduced at the 1954 Mining Show. Designed for deeper holes, the machine handles up to 3000 to 4000 ft of A rod, and accepts up to 2⅞ in. flush-coupled rod. Large hoist uses planetary gears, and gas, diesel or air powered options are available.

Damco's AR-1250 and AR-2000 Drill Rigs: Shown at right above, these two rotaries differ only in size, and are designed to mount on large International Trucks. Weights are 9250 or 11,856 lb, and capacity is 1500 or 2200 ft with 2⅜ drill pipe. Units are also suitable for core drilling.

The Chollet Project, Stevens County, Washington

Fig. 1—View of Selkirk Mountains looking east. Columbia River in foreground. Arrow indicates location of Chollet prospect, Stevens County, Washington.

by M. W. Cox and V. F. Hollister

EXPLORATION for metallic mineral deposits is carried on by those special adaptations of methods which the explorer believes will yield most economically or satisfactorily the particular answer sought. In this project the usual methods of geologic observation, recording, and interpretation, when combined with magnetic geophysical methods and geochemical soil sampling, led to disclosures of appreciable zinc mineralization where none was visible in surface exposure. Since 1945 considerable work has been done with geochemical prospecting methods, chiefly in determining the presence and distribution of various elements existing in minor amounts in rocks, soil, vegetation or waters of mineralized areas. Such work, in which the U. S. Geological Survey has taken the lead, finds a ready place in the field repertoire of the exploration geologist as a supplement, not a substitute, for other methods.

The Chollet project was carried out in 1951 by the American Smelting & Refining Co. near its Van Stone mine in northern Stevens County, Wash., in the area shown in Fig. 1.

The Van Stone mine is located in the Onion Creek drainage of the Selkirk Mountains, midway between the towns of Colville and Northport, Wash., and some twenty airline miles west of the Metaline mining district. Its zinc-lead orebodies, currently yielding about 1000 tpd of ore, occur as bedding replacement deposits in the middle Cambrian Metaline formation near an intrusive granodiorite contact. The target of exploration at the Chollet prospect was a similar geologic environment along the intrusive contact about 5 miles west of the mine.

Geographic Setting

The Chollet ground covers a north-facing slope at 3000 to 4000-ft elevation. Second-growth jack pine and tamarack with some hemlock and yellow pine make a thick forest cover. A heavy underforest of alder, willow, and lesser shrubs occupies the draws, see Fig. 2. Grassy slopes appear at higher elevations. The lower slopes are underlain by a thick blanket of glacial till and alluvium so that outcrops are scarce; however, perhaps 50 pct rock exposure prevails at higher elevations.

This part of northern Washington annually receives about 25 in. of precipitation, which largely falls as snow in the winter months. Summers are dry with occasional rainy periods.

General Geology

The Van Stone mine and the Chollet prospect lie along the southern margin of a westerly extending lobe of the Kaniksu batholith, one of the series of granodioritic masses that are intrusive into Cretaceous and older rocks in northern Washington and southern British Columbia. The margin is composed of complexly deformed Paleozoic sediments ranging in age from the lower Cambrian Maitlen phyllite on the east, through middle Cambrian Metaline formation (limestone and dolomite), to Ordovician Ledbetter slate on the west. In general the formations strike N10 to 50E and dip steeply northwestward, although dip reversals and minor folding occur. This general rock distribution is shown on Fig. 3.

In this area the Metaline formation, which is the host rock for mineralization, appears to be of about 4000-ft thickness that can be conveniently divided into the same three units defined by Park and Cannon[1] for the Metaline area. The basal part consists of 1000 ft of interbedded white limestone, argillaceous limestone, and gray silty argillite. The middle part, approximately 1500 ft thick, consists of fine-grained black, gray, and white dolomite. This unit also contains minor interbedded limestone. The upper part is a gray massive limestone about 1500 ft thick that grades upward into slaty limestone and slate capped locally by a thin black jasperoidal dolomite which is either the uppermost member of the Metaline formation or the basal member of the overlying Ledbetter (Ordovician)

M. W. COX and V. F. HOLLISTER, Members AIME, are Staff Geologists, Northwestern Mining Div., American Smelting & Refining Co., Wallace, Idaho.

Discussion of this paper, TP 4073A, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, March 31, 1955. Chicago Meeting, February 1955.

The Transactions papers appearing in Mining Engineering during 1955 will subsequently appear in AIME Transactions Volume 202 and may be permanently referenced to that volume.

Fig. 2—Photograph of trench No. 1, Chollet property, showing overburden and type of vegetation.

formation. Thin lenses of dolomite also occur in the limestone in the upper part of the formation. The Ledbetter slate contains abundant graptolites, but no fossils have yet been found in this locality in the underlying Metaline. No marker beds have been found, and the general paucity of the outcrops, together with structural complexities, obscures details of the Metaline stratigraphy. At the Chollet prospect the limestones and dolomites are converted at and near the intrusive contact into white coarse-grained marbles; only minor *contact* silicates are developed. Argillaceous members are, however, converted to biotite and chlorite schists and phyllites.

Mineralization found by this investigation on the Chollet ground probably occurs in the middle Metaline dolomite about 2700 ft stratigraphically below the Ledbetter contact. Mineralization at the Van Stone is believed to occur approximately 2200 ft stratigraphically below the Ledbetter, and the large orebodies of the Pend Oreille and Grandview mines in the Metaline district occur within 300 ft of the contact in the upper part of the Metaline.

The zinc and lead mineralization found in northeastern Washington appears to be post-intrusive in age, but it belongs to that same era of mountain building as the granite. It is definitely older than Tertiary (Oligocene?) volcanics that outcrop a few miles west of the Chollet prospect.

Pleistocene glaciation caused major scouring of the area which is reflected in the present topography, but the major effect is a widespread mantle of till and outwash sands and gravel. In the vicinity of the Van Stone and the Chollet this blanket covers 85 to 90 pct of the surface.

Field Work

A general geologic reconnaissance of a large area west of the Van Stone mine disclosed structural and stratigraphic conditions on the Chollet ground that seemed to warrant serious exploration, even though the only mineralization seen was trace of sphalerite in an area of abundant barren outcrop. No mine workings were known in the area. Detailed bruntontape surveying pointed up the lack of outcrop and the impossibility of evaluating the property solely by observational methods. Consequently a grid was established of lines at 250-ft intervals with stations 100 ft apart for about 1½ miles along the favorable area selected by the reconnaissance. The grid covered up to ½ mile northwesterly and southeasterly across the supposed position of the granite-Metaline contact.

A magnetometer survey of the grid was made to define the area underlain by calcareous rocks as well as to locate the Metaline-granite contact. Soil samples were taken at all the stations thus determined to be within the area of calcareous rocks.

Magnetic Data: A Ruska vertical system magnetometer having a sensitivity of 10 gammas was used for station measurement and an Askania magnetometer of the same sensitivity, attached to an automatic recording device, determined the diurnal variation. (The high sensitivity was used for detection of magnetic pyrrhotite associated with the deposits at the Van Stone property. Many small magnetic anomalies there were interpretable mainly by their continuity from profile to profile.) With the magnetometers adjusted for the latitude at Northport, Wash., the Metaline limestone and dolomite were found to give readings of about 100 gammas, while readings over the granodiorite averaged 500 gammas. Highs over the schist tended to be more erratic and higher than those above granite. Interpretation of vertical intensity profiles easily outlined the granite and schist areas and suggested that their contacts with the calcareous rocks were steep. Interpretation of second derivative contour mapping suggested that parts of the calcareous rocks were underlain at depths of a few hundred feet by granite.

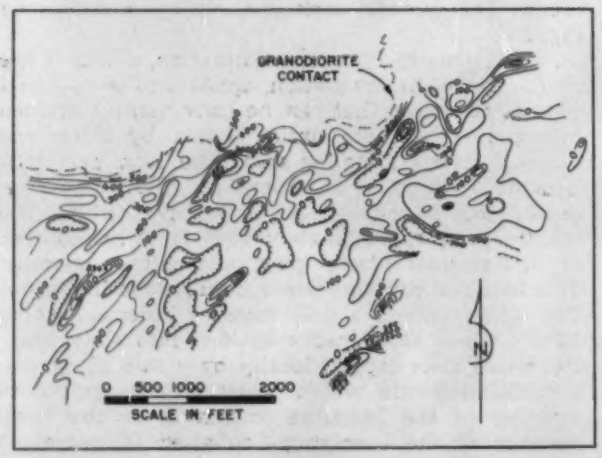


Fig. 4—Magnetic contours, Chollet prospect. Contour interval 100 gammas.

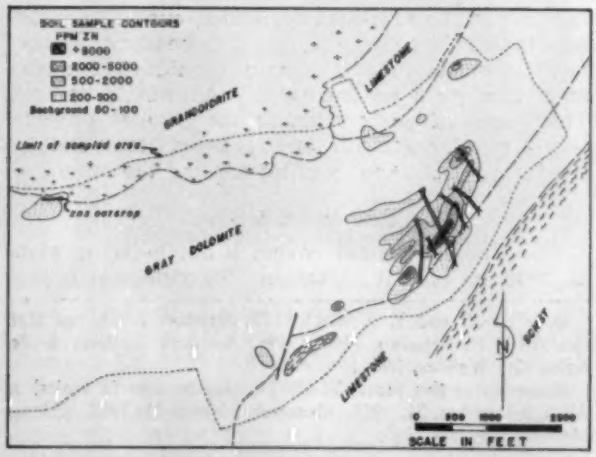


Fig. 5—Detail plan of Chollet prospect. Contacts are based on outcrop and magnetometer data.

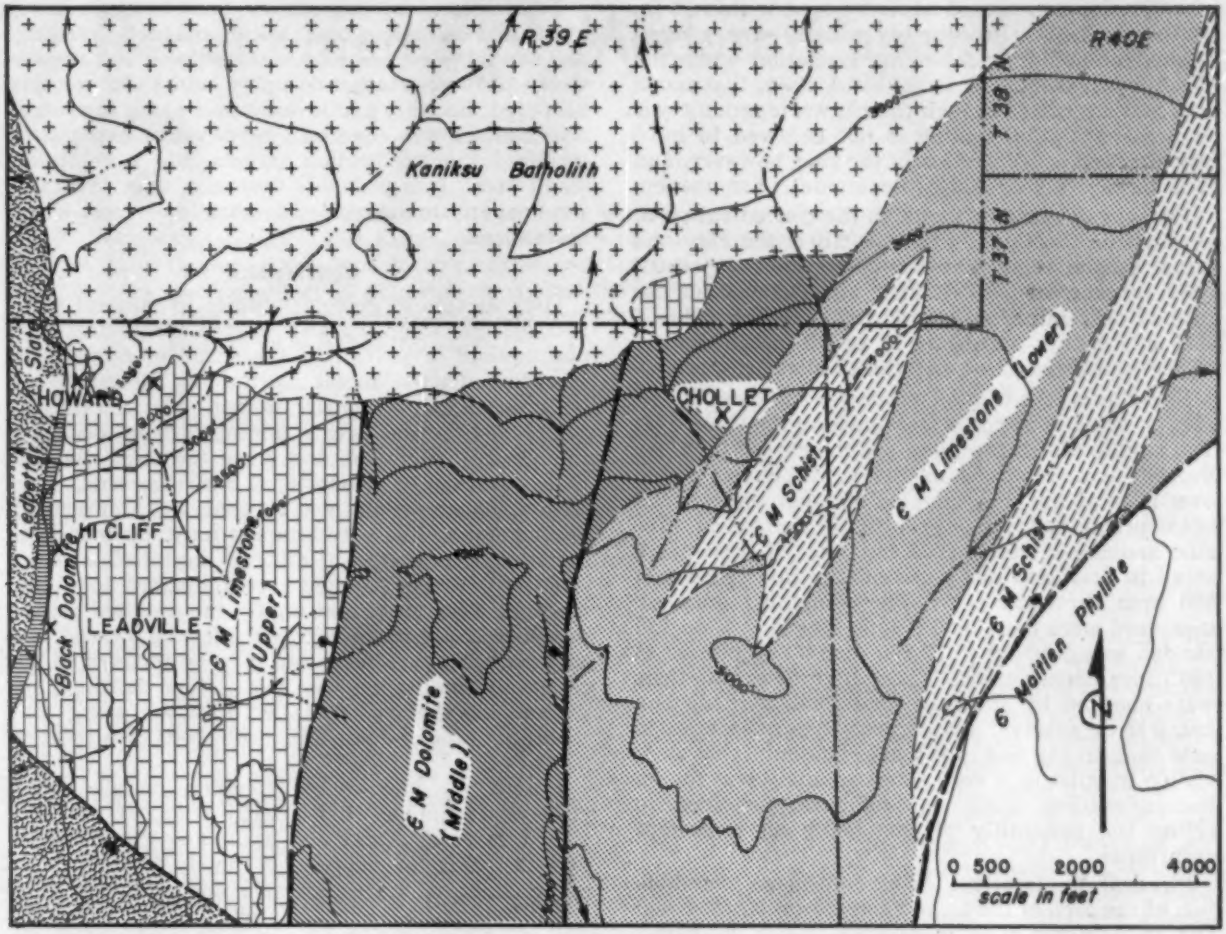


Fig. 3—Map showing local geology of Chollet prospect.

The magnetic contour map, Fig. 4, illustrates the correlations between the rocks and the contours of the magetic values.

Geochemical Data: Methods of soil sampling and metal determination outlined by a USGS publication[3] were, in general, used on the Chollet project. Only the zinc content of the samples was determined. Lead was found to be very erratically distributed in the experimental samples and was not thereafter determined. The lead content of a typical Metaline formation zinc-lead deposit in this area is very low.

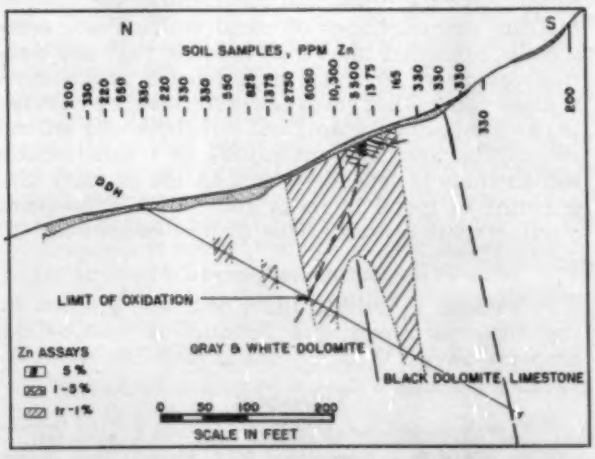


Fig. 6—Typical cross-section, Chollet prospect. Contacts are based on outcrop and magnetometer data.

Experimental soil sampling that preceded the Chollet project, in an area of known mineralization at the Van Stone mine, found unexpected high zinc concentrations in the soil over 50-ft thick till deposits. The zinc apparently still reflected the bedrock zinc content, but it was clearly concentrated within a foot of the present surface. Sampling at deeper horizons in the till indicated a decrease in the zinc content as depth was attained. This concentration of zinc within the upper foot of the deep transported mantle is difficult to explain. The glacial debris is almost entirely composed of granitic or granodioritic rock fragments, and experimental soil sampling in soils over granite revealed an average background of 75 ppm zinc, or approximately the same as the limestones and dolomites. Hence the transported material that covered the barren and mineralized dolomite had the same zinc potential as barren dolomite. The existence of anomalies in the soil over bedrock zinc covered with 50 ft of till is in itself difficult to explain, but the method of concentration is beyond the scope of hypotheses yet suggested.

Coincidentally the upper 12 to 18 in. of the till is uniformly thoroughly mixed. Apparently, following final deposition of the till and recession of the glaciers, frost heaving or some allied process jumbled the upper part of the till. Below the mixed till crude stratification can occasionally be seen, but the

stratification can almost never be seen within 18 in. of the surface. (Presumably mixing was accomplished immediately following glaciation when the climate was colder. It is doubtful, then, that much zinc had migrated through the till while mixing was in progress.) The mixing is not believed to have any effect on concentration of the zinc, however, and it is merely a confusing coincidental phenomenon.

Perhaps the largest factor in the concentration of zinc within the upper limits of till is the clay and minor carbonaceous material (plant debris) present near the surface. Weathering since glaciation has formed only minor amounts of clay in the soil and this only within the top 18 in. of till in the vicinity of the Van Stone mine and the Chollet prospect.

Samples on the Chollet ground were taken in the area of calcareous rocks at a uniform depth of 6 in. The results of this sampling are shown in Fig. 5. An average content of 50 to 100 ppm Zn was found over most of the area sampled whether the soil was of calcareous bedrock or granitic till derivation. Five zinc anomalies were found but four of them were small in area and had a maximum zinc content of 500 ppm Zn (0.05 pct). The remaining anomaly measured more than 2000 ft long by 800 ft wide and yielded assays of up to 10,300 ppm (1.03 pct, 50 to 100 times background). These high determinations were checked by standard analytical methods and found to be substantially correct. It is of interest to note that, in the one spot where zinc minerals were visible in outcrop, a very small anomaly was found. Barren outcrop alone was sufficient, however, to refute the possibility of this being an important occurrence.

Physical Exploration: After careful re-examination of the area of the large anomaly failed to reveal any mineralized rock in outcrop, seven bulldozer trenches were cut down to bedrock. All the trenches, shown on Fig. 5, exposed some zincy gossan and a little sphalerite in dolomite below a capping of 6 in. to 12 ft of crudely stratified granitic till. Below zinc anomalies of 1000 ppm or less only traces of mineralization were found. One trench along the highest anomaly (10,300 ppm) disclosed 5 ft of mixed red gossan and sphalerite assaying 7.9 pct Zn, and for 65 ft the zone averaged 2.2 pct Zn.

Diamond drillholes penetrating the mineralized zone at a depth of 200 to 300 ft below the trenches found the mineralization to be deeply oxidized. A typical cross-section through a trench and drillhole is shown in Fig. 6, together with the soil samples originally taken. The unoxidized material consisted of sphalerite and fine-grained pyrite replacing fine-grained dolomite along bedding and small fractures.

Evaluation of Results: Trenching and drilling of the principal geochemical soil anomaly at the Chollet prospect disclosed a zinc deposit below complete soil and till cover. The zinc occurred directly under the highest anomaly, although the average hill slope in that vicinity is 27°. Fresh till up to 12 ft thick rested directly on deeply weathered dolomite enclosing the zinc mineralization. Probably most of the oxidation of the zinc deposit occurred prior to glaciation. No significant amount of zinc was found below anomalies of 1000 ppm or less, and little anomaly resulted from a partly oxidized zinc deposit that cropped out. The soil sampling accurately indicated the mineralized zone subsequently exposed, but no reliable conclusions could be drawn as to the grade or commercial value of the deposit from geochemical work alone.

Total cost of cutting survey lines through heavy brush and on steep slopes, taking magnetic readings and soil samples, mapping, and assaying was respectively $3.70 per station occupied, and $5.95 per acre surveyed. Roughly a mile and a half along the intrusive contact was covered and physical exploration localized the exploration targets into a relatively small area. It is probable that in a more favorable physical environment a somewhat lower cost would be realized.

Conclusions

Used as aids to geologic studies in mineral prospecting, soil sampling and related techniques offer one method of extending the scope of human observation of actual metal distribution. Since it would be impractical, however, to run grid surveys to sample all the soil over a mining district, desirable though this might be, and since thorough district-wide coverage by geophysical measurements, other than airborne, would also be generally impractical, application of these techniques must be narrowed down. The first step in mineral exploration would seem still to be geologic reconnaissance to obtain regional, then local, and finally the detailed setting in which a particular prospect may be viewed. By this method alone, attention may be focused on the relatively small areas that merit more thorough appraisal, whether such smaller units are along controlling faults, or folds, favorable beds or alteration zones.

Except for deposits of common metals where changed technology has greatly changed the particular mineral economics, as in low grade copper deposits, and for deposits of newly valuable elements such as the radioactive and titanium minerals, it is unlikely that merely examining known deposits in the heavily prospected U.S. will in the future disclose important concentrations of metals hitherto overlooked. It is increasingly necessary to rely on geologic interpretation of structural, stratigraphic, mineralogical, or hydrological guides to mineral deposits and concomitantly on the newer methods of examining features of the earth's crust formerly little studied. No over-simplified applications of *accepted* exploration technique will do. In every area it is necessary to draw on all past experience, then to improvise and experiment until a satisfactory adaptation of general principles of earth sciences and technology is evolved.

In the Northport district geologic mapping from air photos and on the ground, magnetometer work to sort out rock types, and geochemical sampling to indicate concentrations of metal will indicate completely concealed zinc-lead deposits that are partially oxidized. Whether such deposits are of commercial value is not yet predictable merely by studying and sampling the area and soil above and around them. The area and magnitude of a geochemical soil anomaly is dependent both on the primary distribution of metal in rocks and on the subsequent physiographic history of the district concerned.

Acknowledgment

Permission to publish these data was granted by the American Smelting & Refining Co. and by the property owner, C. C. Chollet of Colville, Wash.

References

[1] C. F. Park, Jr., and R. J. Cannon, Jr.: Geology and Ore Deposits of the Metaline Quadrangle, Washington. *USGS Prof. Paper 202.*

[2] H. W. Lakin, R. E. Stevens, and H. Y. Almond: Field Method for the Determination of Zinc in Soil. *Economic Geology*, 1949, vol. 44, pp. 296-306.

Requirements of Modern Paper Clays

The clay particles of 2 microns or less required for modern paper coating are predominantly flat plates, lying smoothly on the sheet and producing a high gloss. Operating speeds of today's coating machines necessitate a clay composition of 60 and sometimes 70 pct solids as against the 35 to 40 pct required in the past. Since clays in suspension may solidify in flow, only those of intrinsically low viscosity can be used as high coating solids.

by C. G. Albert

THE literature of paper technology contains a number of articles having reference to developments in the field of coating and filler clays for use in paper manufacture. Much of this information has not been included in mining publications and has therefore not been readily available to all in the mineral industry. Recent developments in this field, including spray drying of clays, are presented here.

U. S. Bureau of Mines figures for 1952 indicate that the paper industry consumes more than 50 pct of all kaolin produced and sold in the U. S. As most of the kaolin used by the industry comes from Georgia producers, the fraction of their output destined for paper use is thus appreciably higher than 50 pct. Small wonder that the kaolin industry, especially in Georgia, is highly sensitive to the quality requirements of paper mills and must respond promptly to technological developments in paper manufacturing.

The paper industry itself is not the ultimate consumer. For the greater portion of the clay the end product is the printed page, and the demands of printing and publishing have sparked some of the technological advances in paper making which have, in turn, brought about methods employed in the kaolin industry.

As compared with the product of 20 or 25 years ago, one of the most striking characteristics of the graphic arts today is the mass production of quality printing of fine pictorial work, much of it in full color. During this time periodicals with printing standards close to those of yesterday's *slick-paper* publications that were printed on a slow schedule and for a limited circulation have grown to the point where they go out to many millions of readers, often at weekly intervals. The complexity of technological improvements brought about by this increased circulation is probably not appreciated even by technical people, unless they have had reasonably close contact with the industry. The advance has come about through developments not only in the art of printing, but also in the field of paper making and even at the level of clay mining and processing.

The smoothness required for faithful reproduction of the kind of printed matter under consideration is attained with a clay-coated paper. Since the distribution expense of the publication will depend to a great extent on its weight, the paper used must not be too heavy. This means a lower *basis weight* than was normal for conventional clay-coated papers some 25 years ago. And for this mass production market it becomes necessary to provide a paper having these and all the other required characteristics at a very moderate price—not the premium price conventional clay-coated papers formerly demanded.

This challenge has been met by a new method of producing coated paper. In the past, application of clay coating to paper was a conversion operation, performed separately from the making of the base sheet. The newer development is called *machine coating*. Here application of the coating is an integral step in a continuous process by which wood pulp, clay, and other ingredients are manufactured into a sheet of coated paper. Many more problems are involved in this procedural change than are apparent at a casual glance. The coating operation, for example, must function at much higher linear speed than could be obtained with coating mechanisms previously employed. The application machinery developed to meet this requirement necessitated changes in composition of the coating *color*.* This created new requirements, summarized below, for the clay employed as coating pigment.

In addition to smoothness, a relatively glossy printing surface is needed, and to a large measure it is the function of the coating clay to make possible the development of both these surface characteristics. Traditionally, pigments such as satin-white, prepared by reacting lime with paper-makers' alum, were used to assist in producing a high finish. However, economic considerations and others preclude large-scale use of such material in the new processes. In the 1930's Maloney[1] discovered that a certain particle size fraction of kaolin, consisting

* In the paper industry the wet coating composition is referred to as *color*, although it is usually white.

C. G. ALBERT is Assistant Director of Research, Minerals & Chemicals Corp. of America, McIntyre, Ga.

Discussion of this paper, TP 4074H, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, Feb. 3, 1955. Chicago Meeting, February 1955.

predominantly of particles less than 2 microns, exhibited exceptional gloss-imparting properties. Coating clays in use today are almost without exception particle size fractions of this general type, with most of the particles coarser than 2 microns eliminated. Only in recent years did the reason for this gloss-imparting characteristic of particles of particular size become evident, although the fact had long been used to advantage. Woodward and Lyons,[2] by careful electron microscope study, found that there was a general change in shape of the clay particles at about the 2-micron dimension, as measured by sedimentation methods. Particles coarser than this size tend to have the form of cemented stacked aggregates of plates, more or less vermicular in shape. Fig. 1 shows a typical particle in this size range. The particles finer than 2 microns are predominantly flat plates, about one-tenth as thick as their nominal diameter. Fig. 2 illustrates this characteristic platey structure. It is easy to see how these thin flat platelets, when spread upon the paper web, assume a preferred orientation, lying flat on the sheet. They thus produce a smoother surface, capable of specularly reflecting light to give rise to the gloss effect observed by Maloney.

The processes for coating paper on the paper machine operate with coating compositions containing a minimum of water. This is made necessary by the high operating speeds, for one thing, and the resultant problems involved in drying the coated sheet. Thus while coating *colors* used in the past commonly contained only 35 to 40 pct solids by weight, *colors* for machine coating are normally above 60 pct and in some instances approach 70 pct by weight. Instead of having slightly more than 1½ lb of water to make 1 lb of solids flowable, the newer compositions offer only ½ lb, a threefold reduction. If anything, the requirements as to flow properties in the machine-coating processes are more critical than ever, and this combination of circumstances has made it necessary for everyone concerned with the technical aspects of coating clay production to know something about rheology. Suspensions of clay do not behave like true liquids as to flow. They usually do not have a fixed viscosity, but instead their flow characteristics depend on the circumstances under which they are observed. Some suspensions are fluid as long as they are not disturbed, but thicken up or even, in severe cases, become solid when agitated. Such systems are designated as *dilatant*. Quite a different situation is represented by thixotropic systems, which exhibit a *false body* or even a gel structure when at rest but become more fluid when subjected to shearing forces.

The relatively low solids coating colors employed in conventional paper coating had nearly Newtonian or even slightly dilatant flow properties. Clays that were not excessively viscous in aqueous suspension were generally desirable, but flow properties were not highly critical, since it was possible to make considerable adjustment by varying the adhesive or the solids content of the coating. With the advent of high-speed roll coating the picture was drastically changed. The necessity for high coating solids made it essential that the clays have an intrinsically low viscosity. It became equally important that the clay aid in imparting thixotropy to the coating mixture, so that it would perform properly under the conditions of rapid shear encountered in the coating nip and produce a smooth level coating.

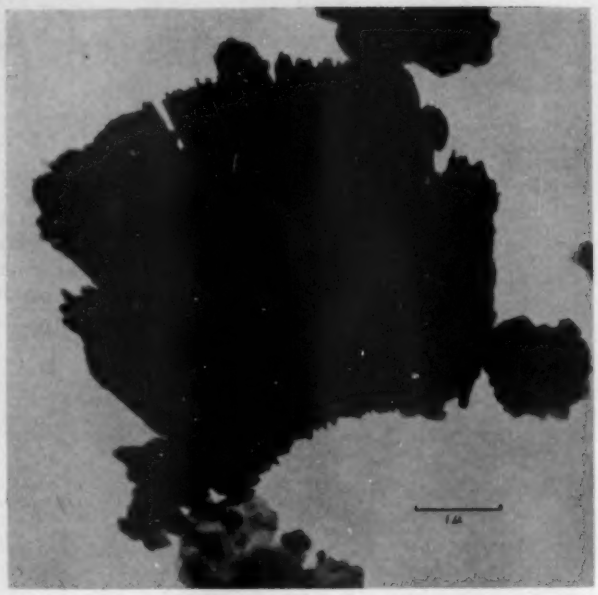


Fig. 1—A typical clay particle of over 2-micron size.

To a degree, the producer of coating clays can solve his problem, insofar as rheology is concerned, merely by having the foresight to possess an extensive deposit of uniform crude clay with the desired flow properties. Nature does not seem to have provided such deposits generously. However, systematic prospecting of deposits with a core drill, coupled with intensive study of the rheology of core samples and selective mining and blending of crude clays, can do much to maintain the necessary level of viscosity. The particle size fractionation, a universal step in producing coating clays, increases their thixotropy-imparting characteristics. Some work has been done on modifying the flow properties of clays, to make low viscosity clay from high viscosity crude. Lyons[3] suggests that extremely fine material, presumably bentonitic, is the principal cause of high viscosity and that reducing the quantity of such material by means of a high-speed centrifuging procedure can alter the flow properties of the clay to a marked extent and in a favorable direction. Millman[4] has found that certain types of mechanical work, applied to clay under prescribed conditions, cause a major reduction in viscosity.

If the coating color being applied by a high-speed roll coating machine is not thixotropic, if for example it is dilatant, the application roll will have a tendency to chatter and the resultant coating will have a definite pattern—a rough surface showing *piling* results unsuitable for fine printing. Another type of coating defect results from the presence of any oversize particles in the coating mixture whether they be undispersed clay or contaminating non-clay impurities such as sand or grit. Such material becomes imbedded in the coating roll, producing small *skips* in the coating which show up prominently when the paper is printed. The high solids of the coatings make it much more difficult than in the past for the paper coater to put the color through screens of sufficiently fine mesh to remove undesirable material of this sort prior to its application to the paper. The burden is thus more than ever upon the clay producer to deliver a truly grit-free product. Permissible residue standards have been lowered to the point where the material remaining on a 325-mesh sieve in modern acceptable coating clays

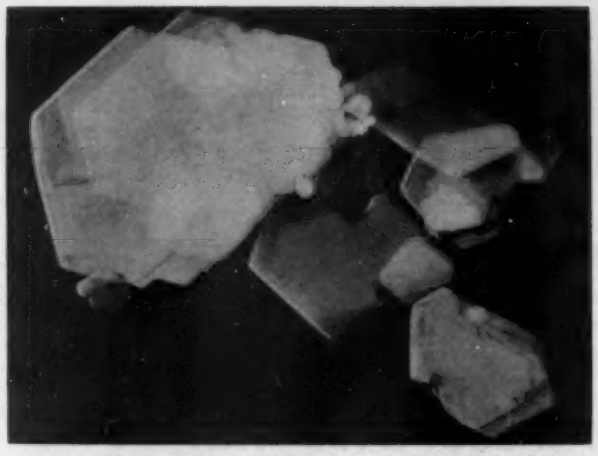


Fig. 2—Platey structure characteristic of clay particles less than 2 microns.

is now expressed normally in thousandths of 1 pct by weight—and only a very few thousandths. Meeting such standards is accomplished in part by increased vigilance to eliminate contamination of clay during processing. The particle size fractionation step, removing as it does essentially all particles coarser than a few microns in size, effectively eliminates gritty material present in the crude clay as mined. Every precaution is made to prevent subsequent introduction of foreign matter: stainless steel piping is used to minimize contamination by pipe scale, fine screening and both wet and dry magnetic separators play their part, and housekeeping and handling practices have been refined in keeping with the strictness of the requirement. Another factor in maintaining the residue-free nature of the clay right up to the point of use concerns increased attention to shipping methods. More and more clay for coating purposes is being transported in covered hopper cars rather than in box cars, not only because of gains in unloading and handling efficiency but also, in part, because such shipments are less subject to contamination en route.

One type of oversize particle contamination can occur despite extreme processing and shipping precautions of the type outlined above. Kaolin is a heat-sensitive material. When, as a part of its processing, it is fractionated to obtain the finer particle size distribution needed for paper coating, this sensitivity is increased. Economic considerations make it ordinarily desirable that clays be shipped at a low moisture content. However, drying clay to the desired moisture content presents a hazard, because agglomerates formed by localized overdrying can be quite as objectionable from an end-use standpoint as contamination with gritty foreign matter.

Spray Drying

One solution to this problem, suggested by Dickerman,[6] has been simply not to dry the clay with heat at all, or at least to dry only a small portion of it, and to handle and ship the clay in the form of a slurry containing 70 pct or more solids by weight. Tank-car shipments of such slurry have had considerable acceptance. Coating clay is basically an inexpensive commodity, however, and shipment is frequently made over great distances. Transportation costs are thus a factor of no slight importance and definitely limit the suitability of undried slurry as a final answer to the drying problem.

A great deal of attention has been paid to drying methods and their control. One system which appears to offer the greatest advantages handles clay much as other heat-sensitive materials such as coffee or milk are handled, performing the drying operation in a spray dryer.[5] Drying is virtually instantaneous so that prolonged exposure to heat is not a problem; the clay is dried out of contact with metal, avoiding the possibility that some portion will adhere to the hot metal surfaces of the dryer and become damaged; the cross-section of the drying particle is small, and the surface is therefore not overheated and case-hardened; and the form of the product is well adapted to modern material handling methods. Clay thus dried can have nearly zero free moisture content and still be free from overdried *hard particles*. Spray-drying installations represent a sizable capital investment, but the overall economics of such processing when it is properly performed have been found to be favorable.

In general, domestic paper clays as mined compare unfavorably with clays from England and with other pigments as to color. For more than 25 years domestic clay producers have made use of chemical bleaching treatments to improve the whiteness of their product. The bleaching processes employed exhibit some variation, but all are believed to involve the use of hydrosulphites such as ZnS_2O_4 in some form. For some time after the inception of bleaching as a unit process in clay production the attainment of a bright, white product was the only goal. Later developments in coating processes and in the adhesives used have introduced a new complication. Complete dispersion of the clay at the required high solids content is adversely affected if the clay contains excessive soluble, ionizable material. Furthermore, some of the adhesive compositions used are sensitive to certain ions. These factors have made it necessary that the clay producer remove nearly all the residual chemicals resulting from the bleaching operation or other steps in his process. The criterion is usually the electrical conductance of water that has been boiled with a sample of the clay in prescribed proportions. Specific resistance of this test water commonly runs, under present standards, as high as 10,000 ohms. The usual remedy for water-soluble impurities is to rinse thoroughly with pure water. Inasmuch as removal of water comprises a good-sized share of the problem of coating clay production, it will be readily apparent that the necessity for thorough rinsing complicates the operation considerably.

It can be seen, then, that developments in the publication field and in the manufacture of paper have greatly increased the consumption of clay, especially for coating purposes. At the same time, they have made the production of satisfactory clays a much more complex operation than was the case 25 years ago. The kaolin industry has been able to keep pace with the exacting requirements imposed upon it. When it is remembered that despite the rigid standards they must meet and the processing these standards necessitate, coating clays are still among the least expensive pigments available, this can be regarded as a particularly impressive performance.

References

[1] W. T. Maloney: U. S. Patent 2,158,987.
[2] L. A. Woodward and S. C. Lyons: *TAPPI*, 1951, vol. 34, pp. 438-442.
[3] S. C. Lyons: U. S. Patent 2,524,816.
[4] N. Millman and J. B. Whitley: U. S. Patent 2,535,647.
[5] G. K. Dickerman: U. S. Patent 2,440,601.
[6] C. G. Albert: U. S. Patent 2,540,182.

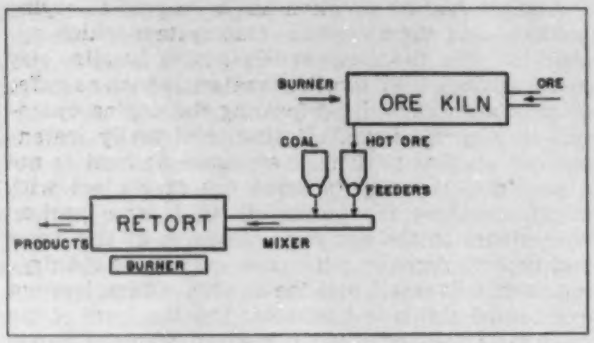


Fig. 1—Flow diagram of the Orcarb process for agglomerating fine ores with low temperature coke shows the pilot operation as it is now constituted.

Agglomerating Fine Sized Ores with Low Temperature Coke

by C. E. Lesher

Two processes for agglomerating fine sized ores with low temperature coke are described. One process (Orcarb) agglomerates ores with limited amounts of carbon; the other (ore-carbon pellets) pelletizes fine sized ores, using low temperature cokes as the binder. Data are presented on the products obtained when taconite, magnetite, and hematite concentrates and several titanium oxide ores were used.

REDUCTION of finely divided oxide ores has long been a major metallurgical problem. Various methods of agglomerating, notably briquetting, sintering, nodulizing, and pelletizing, have been developed and are in industrial use. Carbon is the usual reducing agent for oxide ores and attempts have been made to agglomerate fine ores with coking coal in order to get the metallurgical advantages of intimate contact and increased particle sizes suitable for subsequent smelting or reduction.[1-3]

For the past three years, research has been in progress on two processes for combining fine sized ores with reactive carbon in the form of low temperature coke. By one process, designated *Orcarb*, the ore is coated with coke carbon in amounts limited to that required for reduction and the result is an appreciable but limited increase in product particle size over that of the original ore. The second process, called *ore-carbon pellets*, produces pellets of fine ore bound by low temperature coke.

The first objective was to develop a process for combining an oxide ore with only enough carbon for its reduction, the amount being that derived from the simple reduction equations. The carbon (that amount theoretically required for the reduction of the oxides in an agglomerate with ore), calculated to CO, ranges from 10 pct for zinc calcines or phosphate ores to 21 pct for rutile and 26 pct for silica. The carbon required for reducing iron oxides falls between the extremes—10 and 26 pct. When the carbon in the agglomerate is low temperature coke, reduction by hydrogen may be expected to take place, thus modifying the calculated carbon requirement. On the other hand, in practice, an excess of reducing agent over that required in theory is normally used.

Screen sizes of three iron ores on which the greater part of the experimental work was performed are given in Table I. Most of the testing was done with Freeport (Renton Mine) coal, but Pittsburgh and Elkhorn bed coals were also used.

Table I. Screen Sizes of Certain Iron Ore Concentrates

Screen Size, Tyler Mesh	Taconite, 66.3 Pct Fe		Hematite, 60.6 Pct Fe		Magnetite, 63.8 Pct Fe	
	Pct	Cumulative Pct	Pct	Cumulative Pct	Pct	Cumulative Pct
On 4	—	—	1.5	1.5	—	—
4x8	—	—	0.4	1.9	—	—
8x14	0.05	0.05	0.4	2.3	0.8	0.8
14x28	0.10	0.15	0.8	3.1	19.8	20.6
28x48	0.23	0.38	5.8	8.9	32.9	53.5
48x100	2.22	2.60	24.6	33.5	24.8	78.3
100x200	23.40	26.00	23.0	56.5	11.7	90.0
−200	74.00		43.5		10.0	
	100.00		100.0		100.0	

Orcarb Process

The first objective was to agglomerate the ore with sufficient low temperature coke to provide carbon for reduction, i.e., in the range from 10 to 25 pct. This was accomplished by preheating the ore, mixing with pulverized coking coal, and completing the coal carbonization in a plain steel rotating retort.

The pilot retort, as it is now constituted, is shown by diagram in Fig. 1 and photograph, Fig. 2. Ore is fed into the upper kiln by a screw; it is heated to 900° to 1100°F by direct flame and it is then discharged into an insulating hopper from which it goes

C. F. LESHER, Member AIME, is Consulting Engineer, Pittsburgh.
Discussion on this paper, TP 4058CF, may be sent (2 copies) to AIME by Dec. 31, 1955. Manuscript, Dec. 8, 1954. Chicago Meeting, February 1955.

at a predetermined rate into a mixing conveyer. Pulverized coal also goes to the mixing conveyer at a measured rate from another hopper. The mixture is continuously charged into the lower externally heated retort where the operation is completed and from which the solid product, Orcarb, as well as tar vapor and gas, is continuously withdrawn. The process depends upon bringing the fine sized heated ore particles into contact with the coking coal in such a temperature relationship that the ore is coated with low temperature coke before the denser ore and lighter weight coal segregate. At first, softened bituminous material coats the ore; then the finest sized coated particles will be bonded into larger aggregates if the bituminous material is more than sufficient to coat and impregnate the ore particles.

Uniformity of product, in both size and analysis, depends upon charging the coal into coke while it is in contact with the ore. To accomplish this, the average temperature of the raw coal and ore in the mixer is maintained just below the softening point of the coal; the two materials are well mixed and charged into the revolving retort where they are immediately further heated to complete the carbonization of the coal.

Table II. Analyses of Orcarb by Size*

Screen Size Mesh		Wt Pct		Ignition Loss, Pct	
On	Through	A	B	A'	B'
6	—	4.2	5.0	14.7	7.3
10	6	8.3	8.0	18.5	17.1
14	10	8.0	7.7	18.2	18.0
20	14	11.5	13.5	18.4	17.5
60	20	42.1	45.9	14.7	14.1
100	60	6.7	6.7	10.7	10.5
—	100	19.2	14.1	4.8	4.0
		100.0	100.0		
Weighted average, total		—	—	13.5	13.1
+60 mesh		—	—	16.1	15.0

* Total sample of Orcarb weight 3600 lb.

In this process, the percentage of ore is decreased as the percentage of carbon is increased. This relationship is shown in Fig. 3 where the iron percentages are plotted against the carbon percentages for a series of tests on two different iron ores. The percentages of carbon were determined by combustion, using the procedure for ultimate analysis of coal or coke.

Size distribution and relative analyses of Orcarb made from taconite concentrates are shown in Table II. These figures represent the totals obtained from the production of 3600 lb +60 mesh Orcarb from taconite concentrates. The product that passed the 60 mesh screen was recycled. Each 100 lb charge that was processed contained approximately 17 lb coal, 63 lb ore, and 20 lb −60 mesh recycle. Total carbon in the product was 13.5 pct. Carbon in the +60 mesh product was 15.5 pct. The data in col. *A*, Table II, covers two-thirds of the total production and that in *B*, the final third. The figures designated *ignition loss* are 100 pct less ash for each sample. Ignition loss represents an approximation of the carbon and volatile matter in the product.

Three series of tests, in which the ratio of coal to ore charged was varied, are recorded in Table III. As indicated by the data in this table, the granular product of the Orcarb process is largely within the 6x60 mesh range and the amount of carbon in the Orcarb may be varied from 10 to 25 pct as desired. Of the series 1 (Table III) Orcarb, which contained over 21 pct C, 65 wt pct fell in the +20 mesh size, and two-thirds of 65 wt pct product was +6 mesh.

Table III. Screen Sizes and Analyses of Orcarb*

Size Mesh	Series 1	Series 2	Series 3
	Total Carbon, Pct		
+20	25.0	21.0	19.4
60x20	20.6	16.3	15.8
−60	8.0	6.5	4.0
Average	21.7	14.3	11.3
	Total Iron,† Pct		
+20	45.7	47.9	48.1
60x20	49.5	51.7	53.2
−60	56.0	58.0	60.0
Average	48.0	52.6	55.2
	Wt, Pct		
+20	65.0	31.9	19.5
60x20	16.5	34.6	36.5
−60	18.5	33.5	44.0
	100.0	100.0	100.0

* Orcarb was produced from taconite concentrates and high volatile coking coal.
† Analyses of a number of samples from these tests gave 14.0 to 16.0 pct of the total iron as FeO.

Less than 2 pct of the total weight of the Orcarb in series 2 and 3 was +6 mesh.

The percentage of carbon in the product is limited, by certain metallurgical processes, to that required for reduction; these processes introduce process heat from sources other than by the combustion of carbon in the charge. Some examples in which the process heat applied is independent of that available in the carbon charge are the reduction of zinc oxide in retorts, iron ore in the electric arc furnace, and titanium oxide in the chlorination process. Orcarb will meet the carbon requirements and, for some uses, the size requirements. It will be suitable for use in a fluid reactor, but because of the small size of the product, it will not be suitable for a fixed bed reactor. Orcarb has been found to be an efficient material for reducing iron in the electric open arc furnace.

Ore-Carbon Pellets

The next step in the study of agglomerating fine sized ores with low temperature coke was to develop a process for producing large particle sized aggregates for use in the fixed bed reactor. Thus, the objective became the control of product particle size rather than limited carbon content as discussed previously. Assuming that more coal would automati-

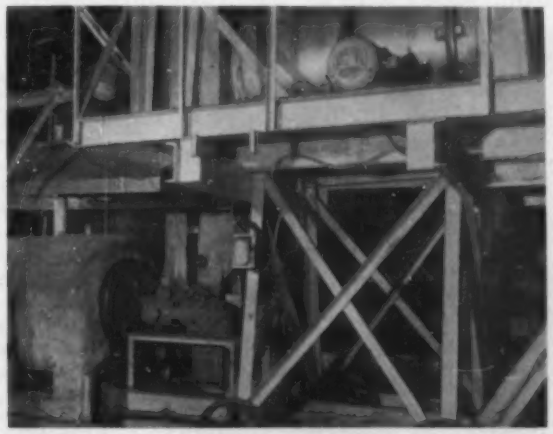


Fig. 2—Orcarb pilot plant is used for agglomerating the ore with low temperature coke. On the upper right is the ore preheating kiln; in the center left are the insulated hot ore and coal hoppers from which the coal and ore are charged to the mixing conveyer; and on the left is the charge end of the externally heated retort. The kiln and hoppers are separately mounted on carriages and can be withdrawn so that the interior of the retort can be inspected.

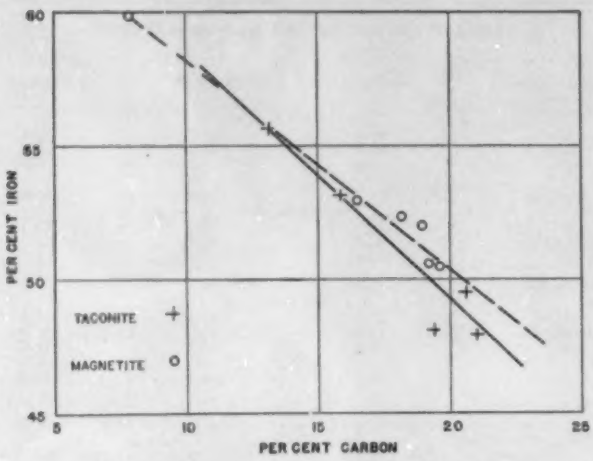


Fig. 3—In the Orcarb process, the percentage of ore is decreased as the percentage of carbon is increased. The graph shows this relationship for two ores, taconite and magnetite concentrates, and coking coal.

cally create larger product, tests were made with the same ores, coal, and procedure used for manufacturing Orcarb. The results were unsatisfactory. No product control resulted, and ore and coal segregated in the retort. The product consisted of irregular masses of coke with low ore pick-up and of much fine and broken material with a high iron content. Cokey crusts built up on the retort walls and on the end of the feed screw.

After conducting tests for several months with different ores and coals, it was decided to try pelletizing these raw materials in the way developed for processing ores with water binder.

Fine sized ores are currently being rolled into pellets with water for a binder. These pellets or *mud balls* are dried, baked, and utilized in subsequent processing. The operation is simple: ore is wetted with water, rolled at atmospheric temperature in a plain steel horizontal cylinder, roughly sized, and dried sufficiently for handling. The variables in the process are the percentage of water binder, diameter and length of the kiln or retort, and the speed of rotation. It appears that the most important variable is the percentage of water used; this may vary with the different charge materials.

Fig. 4 — Photograph of the interior of the ore-carbon pelletizing retort was taken of the operation under load. The retort was halted in process and the load allowed to cool. The unconsolidated charge mixture of coking coal and iron ore concentrates can be seen in the foreground. The mixture is changing to pellets in the center and formed pellets can be seen in the background at the discharge end. The curved pipe in the upper right contains a thermocouple.

The peripheral speed of the pelletizing drum must be such that it carries the wet charge up but not over the drum. Wet pellets are fragile. Different devices and procedures are being used for drying and subsequent hardening, baking, or calcining.

In the process being discussed, plastic coal is used as the binder for fine ore pellets and the pellets are rolled and hardened by the coal in one operation. The one operation, of binding, rolling, and hardening, is accomplished by bringing fine sized ore and coking coal in intimate mixture to the pelletizing drum or retort at a temperature approaching that of the softening point of the coal; the temperature in the retort is increased in order to make the coal plastic as the mixture is rolled. The operation is continuous and the pellets, as they are formed, travel from feed to discharge end of the retort and are removed as solid pellets. Heat to complete the coal softening and to carry it through the plastic condition to solid form is put into the charge through the steel shell of the retort. Tar vapor and gas are withdrawn, of course, as they are produced.

The ore is heated in a direct fired rotary kiln to between 800° and 900°F and is delivered continuously to an insulated mixing conveyer. The coal is fed continuously into the same mixer. The materials are allowed to remain in the mixing conveyer only about 1 min. As the mixture leaves the mixing conveyer, it has an average temperature below the softening temperature of the coal and is fed into one end of the revolving pelletizing retort. This retort is heated by external burners and the temperature of the charge of coal and ore inside is raised at such a rate that the coal becomes plastic as it is being rolled with the ore. Pellets are formed and travel along the retort to the discharge end. Sufficient heat is applied so that the temperature of the product inside the retort and at the discharge end is maintained at 900° to 950°F. The pelletizing process has been accomplished with ores largely finer than 20 mesh and with coking coals having the plastic qualities of either the Pittsburgh or the Freeport beds.

Fig. 4 shows the interior of the pelletizing retort where the material is being changed from loose charge (bottom) to pellets (top). To obtain this picture, the retort was started in normal fashion: ore was charged through the preheating kiln at the rate of 2.5 lb per min and then mixed with the coal which was fed at the rate of 1.2 lb per min. After 45 min of normal operation, the process was sud-

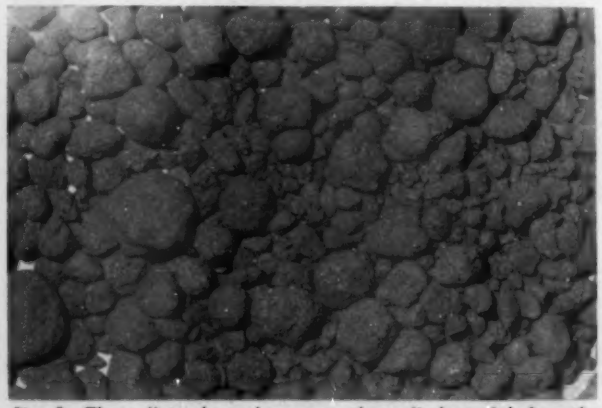


Fig. 5—The pellets shown here were those discharged before the operation was halted for the photograph in Fig. 4. The rough surfaces have been polished and many of the larger pellets have been broken during handling through the discharge screw. A large part of the —¼ in. material in the product can be accounted for by abrasion.

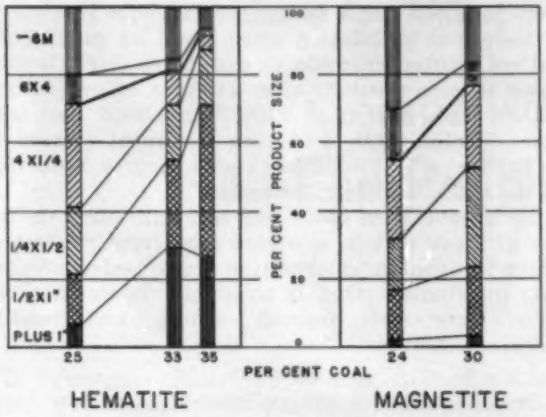


Fig. 6—The diagram shows the product sizes of ore-carbon pellets produced from fine sized hematite and magnetite ores and increasing percentages of coal. The hematite concentrate was the largest ore in order of pellet size and the magnetite was next.

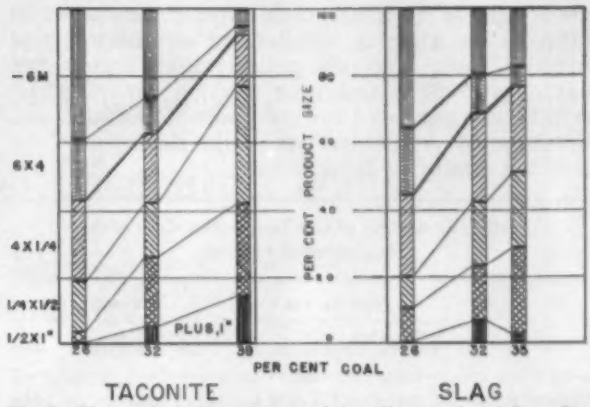


Fig. 7—The product sizes of ore-carbon pellets produced from fine sized taconite ore and slag and increasing percentages of coal are shown in the diagram. Of the four materials shown in Figs. 6 and 7, the taconite concentrates were the finest in particle size. The ilmenite furnace slags were larger than the taconite but smaller than the hematite (largest) and magnetite (second in size).

denly stopped, the burners shut off, and the unit sealed and allowed to cool over night. The retort in Fig. 4 was rotating counterclockwise. The loose unconsolidated charge is seen at the bottom of the photograph and the finished pellets, which are ready to be carried up and into the discharge screw, are seen at the top. The material in the center, between the loose charge and the finished pellets, was between 2 and 3 in. thick and solid when cold. When the solid mass was examined, it was seen that, within 12 to 18 in. from the charge end, pellets were being formed in what was evidently a matrix of plastic material. In the center of the 4 ft long retort, pellets predominated and beyond that point all the material was in pellet form—at first sufficiently plastic to solidify to mass when cold, but at the discharge end comprised of solid separate pellets.

Before the retort was stopped for the photograph shown in Fig. 4, the screen analysis of the product already discharged (Fig. 5) was: 27.4 pct 1x1½ in., 43.7 pct ½x1 in., 16.3 pct ¼x¼ in., 4.4 pct 4 mesh by ¼ in., 0.7 pct 6x4 mesh, and 7.5 pct −6 mesh, totaling 100 pct.

Pellet Product

The pellet product consists of generally rounded particles, the average size of which depends upon the ore particle size and the relative amount of coal in the charge. The size distribution of pellets made from four different ores pelletized with increasing percentages of coal are shown in Figs. 6 and 7. The effect of ore particle size on product size as increasing percentages of coal are used is brought out more clearly in Fig. 8. In this diagram, the weight percent of +¼ in. pellet product produced from each ore is related to the amount of coal charged with the ore. The increase in size is more or less directly proportional to the amount of coal used; the coarsest ore shows 20 to 25 pct more +¼ in. product than the finest. The weighted average size of the pellet product over 6 mesh varies from about 0.275 to 0.5 in. Except for the coarsest ore tested, the weighted average sizes of +6 mesh fall in the range of 0.3 to 0.4 in.

Undersize pellets may be recycled. In the tests that have been made on the recycled material, it has been found that, although a −6 mesh material is much larger than the ore, there is no corresponding gain in product particle size. No doubt this is due to the porosity of the recycled material, since it requires more binder than denser and finer sized ore. This condition can be corrected by pulverizing the material to be recycled. The bulk density of the pellet product made from −6 mesh recycle was 46 lb per cu ft, as compared with 66 lb for product made from ore, bulk density of which was 117 lb.

Analyses

Analysis of the low temperature coke in the agglomerated products has been calculated from the analyses of agglomerates made from an oxide ore (rutile) that is neither oxidized nor reduced during processing. The results presented in Table IV for two tests were derived by first calculating to moisture-free and ash-free bases and then adjusting to the basis of 6 pct ash coke.

Physical Properties of Pellets

It would be desirable, of course, to compare the physical strength of the pellets with other sized material of like nature, in the way in which cokes

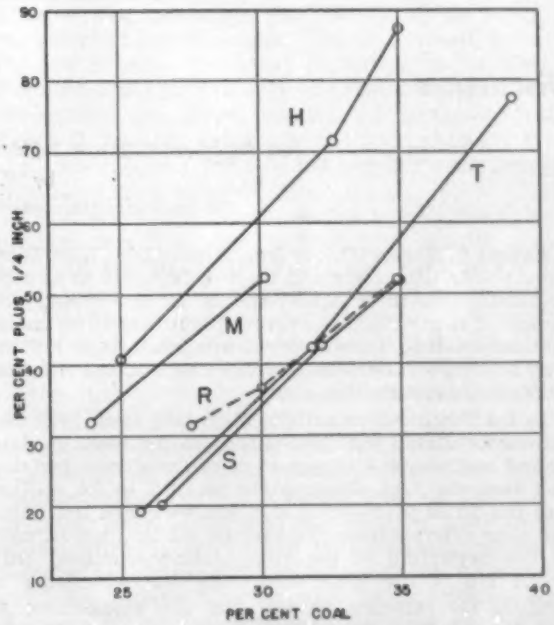


Fig. 8—In the diagram, the four ores of Figs. 6 and 7 are compared with respect to pellet size, with the addition of data from tests with rutile. *H* stands for hematite concentrates; *M*, magnetite concentrates; *R*, rutile; *S*, ilmenite furnace slags; and *T*, taconite concentrates.

are compared by shatter and tumbler tests and fuel briquets by crushing, accelerated weathering, and tumbler tests. Taconite pellets, after drying and baking at 2000°F (more or less) in vertical shaft retorts, are compared for resistance to abrasion and breakage by a tumbler test in the device used for stability testing of furnace coke.

Table IV. Analysis of Low Temperature Coke in the Agglomerated Products

	Test No. 146		Test No. 150	
	Moisture and Ash-Free	Dry	Moisture and Ash-Free	Dry
Volatile matter	17.5	16.5	23.0	21.6
Fixed carbon	82.5	77.5	77.0	72.4
Ash	—	6.0	—	6.0

Actually these ore-carbon pellets are tumbler tested during the manufacturing process. The pellets, while plastic during formation, are rounded and compacted by the centrifugal force imposed in the rotating drum. After solidification, they are as effectively tumbled and tossed as they would be in any other device. Product of less than ¼ in. is believed to be largely the result of this tumbling.

Temperature Susceptibility

Some concern has been expressed over the belief that agglomerates of ore and low temperature coke are highly susceptible to shock when exposed to the temperatures at which reducing reactions take place; the author, however, can find no evidence to support this assumption. On the contrary, there is evidence that this kind of agglomerate is not subject to disintegration, explosion, or shattering when heated to high temperatures, either gradually or suddenly. After exposure to the effects of weather for several years, 2 and 3 in. pieces of Ore-Disco were dropped into a molten slag bath in an electric furnace and withdrawn after about 15 min. They did not shatter, crumble, or disintegrate. No breakdown in size resulted after samples of ore-carbon pellets were heated to 1700°F in closed cast iron pots. The only effect of such treatment seemed to be hardening of the pellets and, of course, reduction in the volatile matter content.

Tests have been made and are continuing on the use of these pellets, manufactured from rutile and ilmenite ores, in chlorination fixed bed processes. The information that is available shows that the pellets are well formed, strong, and readily chlorinated.

Summary

Ore concentrates are pelletized, using low temperature coke as a binder. Fine sized preheated ore and pulverized coking coal are rolled to pellet form and hardened continuously in a rotating externally heated retort. The carbon in the product may be varied from 25 to more than 40 pct. With a given ore, the pellet product size increases as the amount of carbon is increased. These pellets are adapted for oxide reduction in fixed bed reactors and buried arc electric furnaces.

By another process, a product called Orcarb is made from ore concentrates or calcines; in this process the ore particles are coated with a predetermined and limited amount of carbon (in the range of 10 to 25 pct), and the product used is largely between 10 and 60 mesh. Orcarb is suitable for use in fluid bed reactors, open arc electric furnaces, or other operations in which the process heat is externally applied.

References

[1] U. S. Patent No. 1,711,153.
[2] U. S. Patent No. 2,029,309.
[3] C. E. Lesher: Low Temperature Coke as a Reactive Carbon. *AIME Trans.*, July 1950, vol. 187, pp. 805-810.

Discussion

An Agglomeration Process for Iron Ore Concentrates

by W. F. Stowasser

(Mining Engineering, page 473, May 1955; AIME Trans. v. 201)

Robert E. Hagen *(Oliver Iron Mining Div., U. S. Steel Corp.)*—Mr. Stowasser and his associates are to be congratulated on their achievements in developing the design of a pilot agglomerating plant, based on information obtained from experiments made in a laboratory sinter pot, and subsequently constructing and successfully operating this plant.

In his Transactions article, May 1955 (vol. 201) Mr. Stowasser stated that the output of his heat treating strand was about 2 Lt per sq ft of grate area per day and that the fuel consumption was 0.7 to 0.8 million Btu per Lt of product. If it is assumed that the burning zone extends from the back of the ignition furnace to the beginning of the recuperation windbox, only about 1/3 of the grate area over the windboxes is utilized for burning pellets, and the actual rate at which partially dried pellets are burned is about 6 Lt per sq ft of grate area per day.

It may be interesting to compare the above operating data with that obtained at the Extaca plant, where taconite concentrate is treated on a conventional sintering machine using limestone or hydrated lime additives with no recuperation of heat. The entire windbox area is used for burning, and a production rate of 2.5 Lt per sq ft of windbox area per day has been attained at a fuel consumption of 1.8 to 2.0 million Btu per Lt of product, the latter being considerably in excess of that reported by Mr. Stowasser, partly because a circulating load of returns amounting to 28 to 30 pct of the machine feed is used and because no attempt is made to recuperate heat from the waste gases.

With the high capital and labor costs prevailing today, it seems that future development of the downdraft grate pelletizing process should be directed toward taking advantage of the high burning rate of predried pellets and increasing capacity, perhaps at the expense of fuel economy, by decreasing the proportion of grate area utilized by ancillary functions. For example, eliminating the cooling zone and using this area for burning would increase the proportion of grate area available for burning from 33 to 50 pct of the total windbox area, and a proportionate increase in capacity would result.

Analysis of Variables in Rod Milling

Comparison of Overflow And End Peripheral Discharge Mills

by Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom

IN a previous article[1] the authors outlined a study of the variables in rod milling and also reported data from a series of open circuit grinding tests on a massive limestone in a 30-in. x 4-ft end peripheral discharge rod mill. As a second part of the experimental program, an analysis is now presented for the 30-in. x 4-ft overflow rod mill grinding under identical conditions, except that discharge ports on the periphery of the mill shell have been sealed so that the products from the present series overflowed through a 9-in. diam opening in the center of the end plate. A variance analysis has been made of the combined data for the two experiments, and performances of the two mills are compared here.

Included in the first report[1] were descriptions of feed preparation, rod mill circuit, instrumentation and controls, and techniques used to evaluate data. Dependent and independent variables were defined, and variance analyses were made to test the relative significance of variables and to establish magnitude of error for the experiment. Significant data were plotted in various combinations, and conclusions were drawn from the graphs. The procedure and analysis in this series of tests follows the first tests and is not repeated.

Data from the second series are recorded in Table I. Listed in the first three columns are the independent variables of feed rate (1000, 2000, 3000, 4000, and 5000 lb per hr), mill speed (50, 60, 70, 80, and 90 pct of critical), and pulp density (50, 60, 70, and 80 pct). The dependent variables, P_{80}, P_{100}, reduction ratio, slope of the log-log sieve analysis curve, power demand, and Bond work index follow. Of these, only the reduction ratio and the Bond work index were analyzed for significance. Production of new surface as calculated from sieve analyses has not been included for this series because of the questionable assumptions that have to be made to satisfy the formulas involved. The large number of products obtained during the runs precluded the use of surface measurement techniques by the gas adsorption methods at this time; however, samples of all products have been stored for future reference.

To test the consistency of the reporting of the sieved products, an averaged sieve analysis was calculated from the wet-dry plots obtained from the three product samples of each run. The resulting averaged analysis was plotted and the P_{80} selected. The relative deviations of the P_{80}'s from each of the three product samples with respect to the P_{80} of the averaged analysis were then calculated. In only two sets were the relative deviations (6.2 and 9.9 pct) considered excessive. In each of these two sets, one sieve analysis was obviously out of line; hence that analysis was ignored and new averages were computed. This reduced the relative deviations to 1.2 and 2.7 pct respectively. The relative deviations of the product analyses with respect to their averages ranged from 0.1 to 1.4 pct at 1000 lb per hr, 0.0 to 1.1 pct at 2000 lb per hr, 0.2 to 3.0 pct at 3000 lb per hr, 0.3 to 4.3 pct at 4000 lb per hr, and 0.5 to 5.2 pct at 5000 lb per hr.

The relative deviation of the 80 pct passing point for 96 dry sieve analyses of the feed with respect to that of the averaged analysis was 7.6 pct. This slightly higher percentage can probably be attributed to a greater proportion of tramp oversize in a crusher product than is ordinarily found in a rod mill product.

The last column on Table I lists the adjusted work index, which has been used as the measure of efficiency for the various combinations of operating conditions investigated. Efficiency increases as the index becomes lower.

It was reported in the previous paper that the work indexes for the Waukesha limestone used in these experiments decreased as the product size decreased (as calculated from Bond grindabilities). That is, this limestone becomes easier to grind as the material becomes finer. This is unusual, because the work index for most materials as calculated from the Bond grindability has remained constant as the product size decreased or has increased slightly. Table II lists the results of Bond grindability tests at all mesh sizes from 3 to 200 and the work indexes calculated from them.

To remove this variation of work index with product size from the data so that results would apply to any material of constant work index, the work index values shown in Table II were plotted against product size on log-log paper. From this curve (a straight line function in this case), the expected work index for the product size for each of the runs of the experiment was obtained. The work indexes as calculated from the reduction ratio and energy consumption were then divided by the corresponding expected work index. The results obtained are reported in percentages on Table I as adjusted work index and are actually percentages of the work index for the Waukesha limestone at the size in question. Multiplication of the work index value for a material of constant index by these percentages should allow the application of the adjusted work index curves to the material.

Only the adjusted work index values, not the actual experimental values, were used for the variance analyses and for the graphs.

W. MITCHELL, JR., C. L. SOLLENBERGER, T. G. KIRKLAND, and B. H. BERGSTROM, Members AIME, are with the Research Laboratories, Allis-Chalmers Mfg. Co., Milwaukee.

Discussion of this paper, TP 4119B, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, March 7, 1955. Chicago Meeting, February 1955.

Table I. Data for 30-In. x 4-Ft Overflow Discharge Rod Mill*

Test No.*	Feed Rate, Lb Per Hr**	Mill Speed, Pct of Critical	Pulp Density, Pct Solids	P_{80} Microns	P_{100} Mesh	Slope	Reduction Ratio F_{80}/P_{80}	Power Demand, Kw	Work Index, Kwh Per Ton	Adjusted Work Index, Pct
81	1000	50	50	117	8	0.248	108.5	4.07	9.6	143
82		60		105	8	0.337	121.0	4.84	11.0	168
83		70		93	8	0.306	136.6	5.77	12.2	192
84		80		86	8	0.289	147.7	6.45	13.2	211
85		90		97	8	0.338	130.9	6.91	15.1	235
86		50	60	108	10	0.327	117.6	4.04	9.2	139
87		60		99	8	0.315	128.3	4.60	10.0	155
88		70		93	10	0.312	136.6	5.69	11.9	186
89		80		91	10	0.299	139.6	6.54	13.6	214
90		90		97	10	0.288	130.9	7.03	15.1	235
91		50	70	106	10	0.289	119.8	4.13	9.3	142
92		60		96	10	0.300	132.3	4.62	9.8	154
93		70		93	10	0.277	136.6	5.79	12.3	193
94		80		91	10	0.286	139.6	6.46	13.3	211
95		90		99	10	0.319	128.3	6.99	15.4	238
96		50	80	128	10	0.307	99.2	4.01	10.1	148
97		60		113	10	0.272	112.4	4.70	11.5	174
98		70		123	10	0.274	103.3	5.73	14.0	206
99		80		137	10	0.264	92.7	6.01	15.7	226
100		90		140	10	0.283	90.7	6.36	17.0	243
101	2000	50	50	302	3	0.333	42.1	4.67	9.6	115
102		60		235	3	0.343	54.0	5.24	9.4	119
103		70		218	4	0.335	58.3	5.95	10.2	132
104		80		210	6	0.330	60.5	6.95	11.4	150
105		90		224	8	0.337	56.7	7.65	13.2	170
106		50	60	317	4	0.345	40.1	4.59	9.7	116
107		60		260	6	0.328	48.8	5.72	10.8	135
108		70		214	8	0.329	59.3	6.46	10.9	142
109		80		209	6	0.335	60.8	7.20	12.0	157
110		90		238	6	0.322	53.4	7.46	13.4	170
111		50	70	318	4	0.326	39.9	4.48	9.5	113
112		60		278	4	0.325	45.7	5.10	9.8	121
113		70		243	6	0.324	52.3	6.07	10.9	138
114		80		228	8	0.315	55.7	7.02	12.2	157
115		90		230	8	0.329	55.2	7.39	13.0	166
116		50	80	400	4	0.329	31.8	4.43	10.8	122
117		60		315	8	0.312	40.3	5.35	11.2	134
118		70		310	6	0.310	41.0	6.16	12.9	154
119		80		288	8	0.313	44.1	6.76	13.5	164
120		90		305	6	0.300	41.6	6.81	14.0	168
121	3000	50	50	915	⅜ in.	0.371	13.9	4.23	11.7	109
122		60		565	3	0.369	22.5	4.99	10.4	108
123		70		443	4	0.378	28.7	5.92	10.2	112
124		80		392	6	0.374	32.4	6.85	11.0	124
125		90		420	4	0.363	30.2	6.89	11.5	128
126		50	60	1000	⅜ in.	0.362	12.7	4.03	11.8	108
127		60		645	3	0.365	19.7	4.61	9.8	99
128		70		395	4	0.367	32.2	5.73	9.3	105
129		80		395	3	0.365	32.2	6.61	10.7	121
130		90		420	4	0.352	30.2	7.01	11.8	132
131		50	70	730	3	0.371	17.4	4.22	10.0	99
132		60		545	4	0.365	23.3	5.28	10.4	109
133		70		535	3	0.361	23.7	5.90	11.4	121
134		80		490	4	0.358	25.9	6.52	12.0	129
135		90		475	4	0.352	26.7	6.86	12.3	134
136		50	80	740	4	0.359	17.2	4.26	10.2	100
137		60		630	4	0.349	20.2	4.89	10.4	106
138		70		555	3	0.348	22.9	5.66	11.2	117
139		80		468	6	0.351	27.1	6.66	11.9	129
140		90		480	6	0.354	26.5	6.58	12.1	131
141	4000	50	50	1060	⅜ in.	0.359	12.0	3.81	8.7	79
142		60		840	3	0.368	15.1	4.16	8.3	79
143		70		765	3	0.365	16.6	5.09	9.4	91
144		80		555	4	0.357	22.9	5.72	8.6	90
145		90		795	3	0.346	16.0	5.87	11.1	107
146		50	60	2970	¾ in.	0.329	4.3	3.43	18.0	129
147		60		1580	½ in.	0.341	8.0	4.34	13.3	110
148		70		990	⅜ in.	0.354	12.8	5.28	11.5	105
149		80		695	4	0.343	18.3	5.91	10.2	101
150		90		860	3	0.327	14.8	5.89	11.7	111
151		50	70	2670	½ in.	0.319	4.8	3.43	16.3	120
152		60		1220	⅜ in.	0.327	10.4	4.45	11.2	98
153		70		810	3	0.338	15.7	5.20	9.8	94
154		80		840	3	0.339	15.1	5.97	11.6	110
155		90		935	⅜ in.	0.342	13.6	5.94	12.4	116
156		50	80	3700	¾ in.	0.299	3.4	3.46	24.7	168
157		60		2830	1 in.	0.295	4.5	4.15	21.0	152
158		70		1770	¾ in.	0.323	7.2	4.94	16.4	132
159		80		1040	½ in.	0.341	12.2	5.30	11.9	108
160		90		1040	⅜ in.	0.333	12.2	5.65	12.6	115
161	5000	50	50	4900	¾ in.	0.331	2.6	2.93	21.6	138
162		60		3340	½ in.	0.376	3.8	3.73	17.7	123
163		70		2170	½ in.	0.399	5.9	4.39	13.9	107
164		80		1500	⅜ in.	0.370	8.5	5.15	12.1	101
165		90		Mill overloaded			—	—	—	—
166		50	60	4950	¾ in.	0.338	2.6	3.08	25.6	163
167		60		4050	¾ in.	0.343	3.1	3.22	20.9	139
168		70		2420	½ in.	0.382	5.2	4.21	14.7	110
169		80		1750	⅜ in.	0.377	7.3	4.96	13.2	106
170		90		Mill overloaded			—	—	—	—
171		50	70	3550	¾ in.	0.307	3.6	2.97	16.7	115
172		60		3400	¾ in.	0.309	3.7	3.77	19.4	135
173		70		1920	½ in.	0.344	6.6	4.42	12.6	100
174		80		1120	⅜ in.	0.348	11.3	5.14	9.8	87
175		90		1660	½ in.	0.350	7.1	4.90	12.7	103
176		50	80	3650	¾ in.	0.312	3.5	3.07	16.9	116
177		60		2580	½ in.	0.315	4.9	3.92	14.4	107
178		70		2300	¾ in.	0.314	5.5	4.45	14.8	112
179		80		925	⅜ in.	0.326	13.7	5.40	9.0	84
180		90		1010	3	0.318	12.6	5.41	9.6	87

* Data for tests 1 through 80 are published in *AIME Trans.*, 1954, p. 1003.[1]
** Feed, Waukesha limestone. F_{80} = 12,700; F_{100} = 1 in.; slope = 0.603.

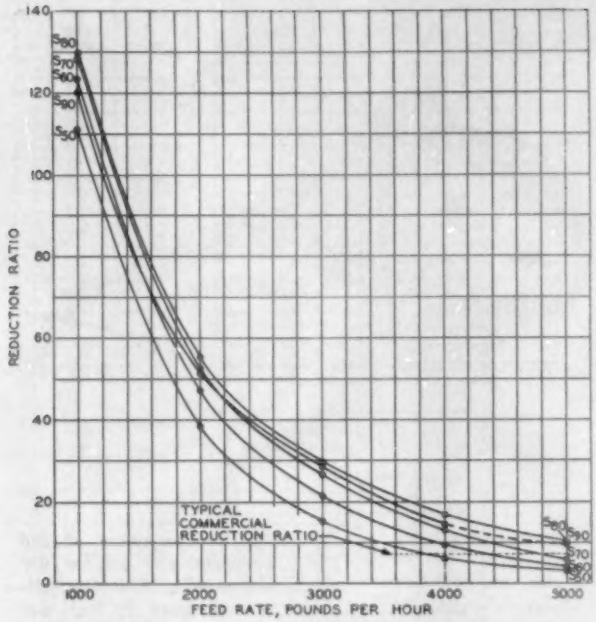


Fig. 1—Reduction ratio vs feed rate for each mill speed. (Averages for four pulp densities.)

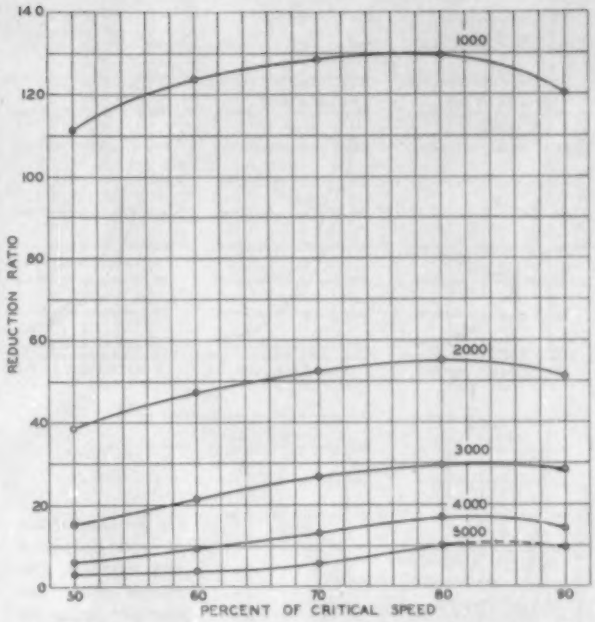


Fig. 2—Reduction ratio vs mill speed for each feed rate. (Averages for four pulp densities.)

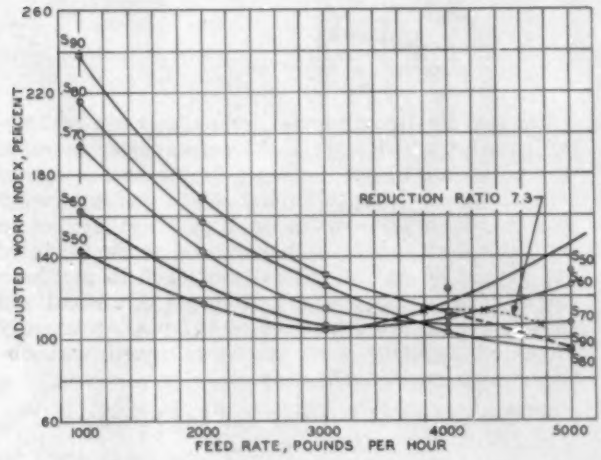


Fig. 3—Adjusted work index vs feed rate for each mill speed. (Averages for four pulp densities.)

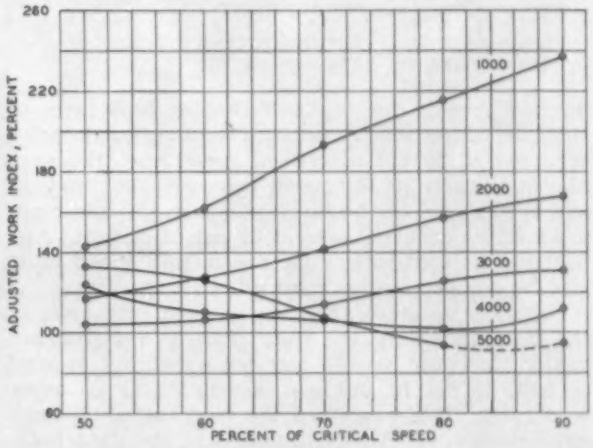


Fig. 4—Adjusted work index vs mill speed for each feed rate. (Averages for four pulp densities.)

Significant Relationships: Overflow Discharge Mill

The technique used for the variance analyses, as described in detail previously,[3] is the same as that used for analyzing the data obtained from this experiment. Since Brownlee[3] has described the development and application of the technique, only the results will be included here.

Reduction Ratio: Feed rate, mill speed, and an interaction of feed rate and pulp density were found to have a significant effect upon reduction ratio, all at the 0.1 pct or the highest level of significance. Because pulp density was not shown to be significant as a main effect, it was averaged out of all of the data. Resulting averages of the reduction ratios were plotted against feed rate for each level of mill speed on Fig. 1 and against mill speed for each level of feed rate on Fig. 2. Fig. 1 shows that the reduction ratio decreased rapidly as the feed rate increased. Fig. 2 shows that maximum reduction was obtained at 80 pct of critical speed for each feed rate.

To determine the reason for the feed rate—pulp density interaction, the data were examined without the pulp density being averaged out. Pulp density appeared to have little effect on reduction ratio at feed rates of 3000, 4000, and 5000 lb per hr. At 1000 and 2000 lb per hr, however, lower reduction ratios were obtained at 80 pct solids than were obtained at the lower pulp densities.

A horizontal line corresponding to a typical commercial reduction ratio of 7.3 is drawn on Fig. 1. The intersections of this line with the curves show that an increase in capacity of 10 to 12 pct was obtained as the mill speed was increased from 50 to 60 and again from 60 to 70 pct of critical.

Adjusted Work Index: Although no test was available for the significance of feed rate it appeared to have a substantial effect on work index. Mill speed was significant at the 5 pct or lowest level, and interactions of feed rate with mill speed and pulp density were significant at the 0.1 pct level. Work index was plotted against feed rate on Fig. 3 and against mill speed on Fig. 4. Pulp density was averaged out of these data also.

Fig. 3 shows that minimum work index occurred at feed rates from 3000 to 5000 lb per hr depending

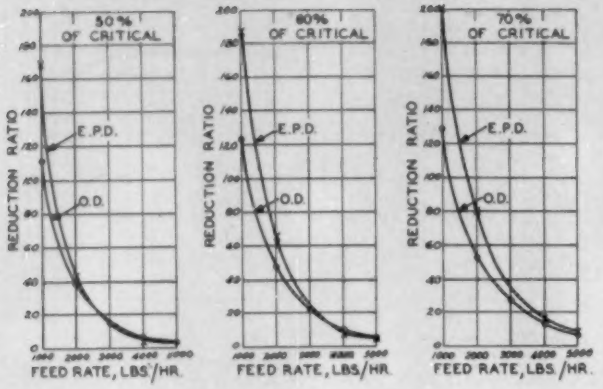
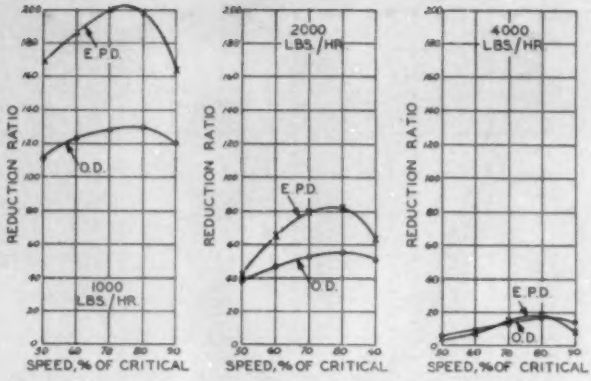


Fig. 5—Comparison of end peripheral and overflow discharge mills. Reduction ratio vs feed rate at five mill speeds.



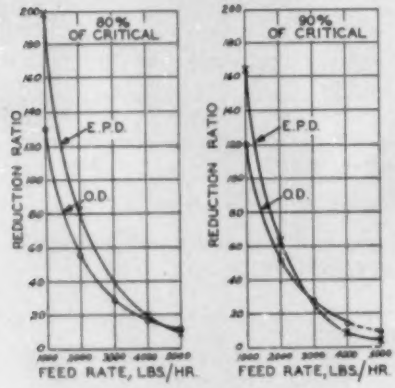


Fig. 6—Comparison of end peripheral and overflow discharge mills. Reduction ratio vs mill speed at four feed rates.

on mill speed. Fig. 4 shows that at feed rates of 1000, 2000, and 3000 lb per hr, minimum work index occurred at 50 pct of critical speed and increased almost linearly as the speed increased, but at 4000 and 5000 lb per hr the speed at which the minimum work index occurred was at 80 pct of critical. Apparently as feed rate is increased, mill speed must also be stepped up for most efficient operation.

Separate variance analyses, at each feed rate, of the data including the pulp density variable revealed that pulp density was not significant at 3000 or 5000 lb per hr but was significant at all other feed rates. This explained the feed rate–pulp density interaction. An examination of the data indicated that at the feed rates where pulp density was significant, higher grinding efficiencies were obtained at 50 to 70 pct solids than at 80 pct solids.

The lowest work index for all operating conditions investigated was the value obtained at 5000 lb per hr and 80 pct of critical speed. With these conditions the reduction ratio was 10.2. Apparently the overflow mill operates most efficiently at a high feed rate and a high mill speed.

Table II. Variation of Work Index for Waukesha Limestone with Product Size

Mesh Size	Rod Mill Grindability, Grams per Revolution	Work Index
3	32.4	15.4
4	21.8	16.7
6	18.3	15.6
8	19.6	12.6
10	15.3	12.4
14	13.2	11.4
20	11.8	10.3
28	10.0	9.55
35	9.10	8.55
48	8.10	7.73
65	6.95	7.12
100	6.01	6.60
150	4.95	6.25
200	4.02	5.97

For a typical commercial reduction ratio of 7.3—the ratio at which a 10 to 12 pct capacity increase was noted for 10 pct increases in the percentage of critical speed—the following work indexes were selected from the curves on Fig. 3: at 50 pct of critical speed and 3800 lb per hr a work index of 114 pct, at 60 pct of critical and 4300 lb per hr a work index of 113 pct, and at 70 pct of critical and 4800 lb per hr a work index of 107 pct. Apparently increased capacity with increased speed was obtained at a greater efficiency.

Comparison of Overflow and End Peripheral Discharge Mills

In general, pulp density had little effect on the performance of either type of mill; however, with the end peripheral mill there was an indication that as feed rate was increased, it should be operated with a more dilute pulp, 70 pct solids at 1000 lb per hr to 50 pct solids at 5000 lb per hr to obtain the greatest reduction and lowest work index. With the overflow mill this trend was not observed. The only effect noted was that at a few feed rates greater reduction ratios and lower work indexes were obtained at 50, 60, and 70 pct solids than were obtained at 80 pct solids.

Reduction Ratio: The variance analysis revealed that reduction ratio was significantly affected by feed rate (5 pct level) and mill speed (0.1 pct level) when both mills were considered. Type of discharge, however, was not significant as a main effect, but only as an interaction with feed rate (0.1 pct level).

For visual comparisons of data for the two mills, reduction ratio was plotted against feed rate at each speed for both mills on Fig. 5 and against speed at each feed rate for both mills on Fig. 6. These figures show that reduction ratio dropped off rapidly for both mills as feed rate increased. In general it was a maximum at 80 pct of critical speed. The interaction between feed rate and mill speed which was

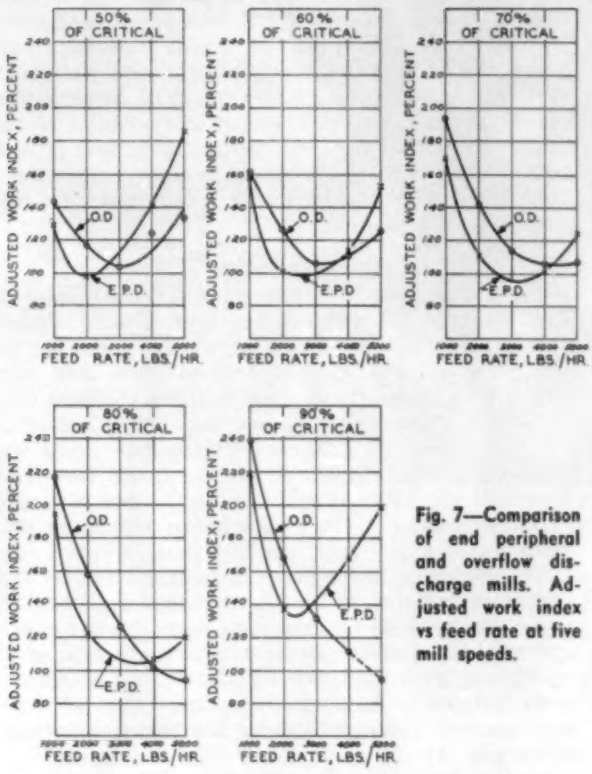


Fig. 7—Comparison of end peripheral and overflow discharge mills. Adjusted work index vs feed rate at five mill speeds.

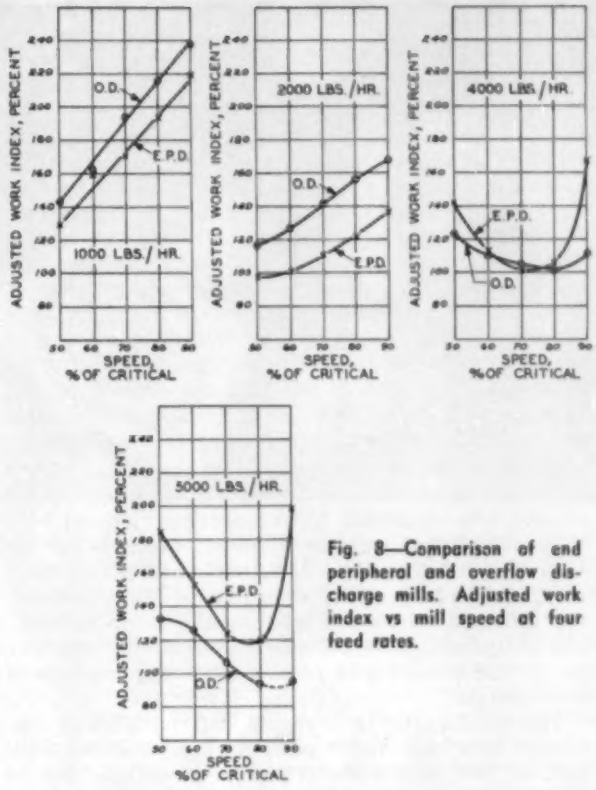


Fig. 8—Comparison of end peripheral and overflow discharge mills. Adjusted work index vs mill speed at four feed rates.

noted for the end peripheral mill in the previous paper does not appear of significance when the combined data are considered.

The significant feed rate—mill discharge interaction noted in the variance analysis can be seen on Fig. 6. There is a difference between the reduction ratios obtained with the two mills at 1000 and 2000 lb per hr. At feed rates of 4000 and 5000 lb per hr, there is practically no difference in reduction ratio except at 90 pct of critical speed. The chief difference between the two mill discharges in regard to reduction ratio is that greater ratios were obtained at feed rates of 1000 and 2000 lb per hr with the end peripheral discharge mill.

At a constant reduction ratio of 7.3, a 10 to 15 pct increase in capacity was noted for both mills as mill speed was increased from 50 to 60 and from 60 to 70 pct of critical. This increase in capacity was obtained in both cases at slightly greater efficiencies.

Work Index: Results of the variance analysis of work index were not clearly defined because all first and second order interactions were found to be significant. Interaction of speed, feed rate, and mill discharge and interaction of mill discharge and speed were found to be significant at the 5 pct level. Interaction of feed rate and speed and interaction of feed rate and mill discharge were significant at the 0.1 pct level. Mill discharge was not significant as a main effect and feed rate and mill speed could not be tested for significance.

Separate variance analyses of the data for each feed rate revealed that mill speed and mill discharge significantly affected work index at all feed rates.

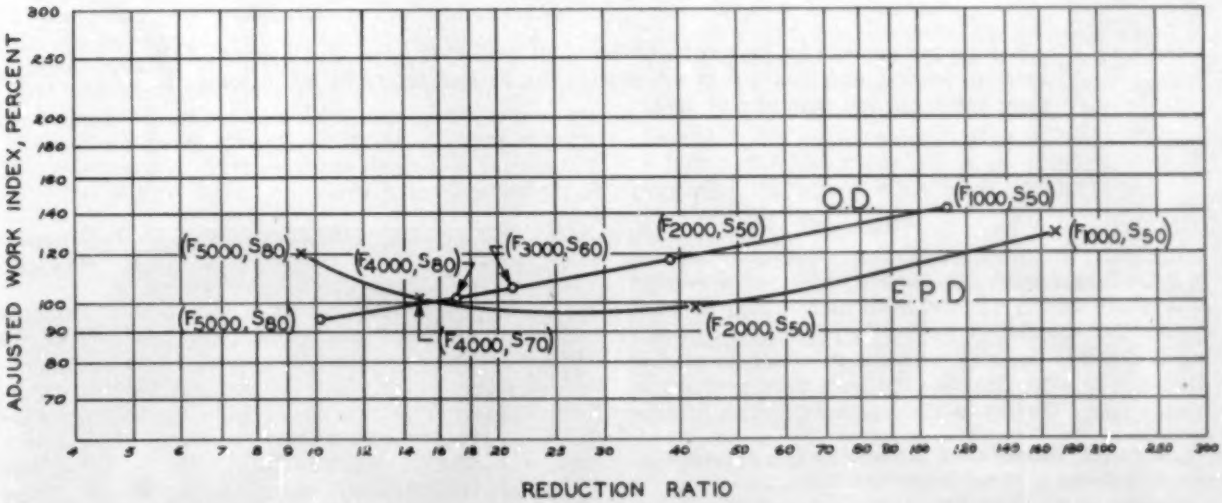


Fig. 9—Comparison of end peripheral and overflow discharge mills. Adjusted work index vs reduction ratio at most efficient speed for each feed rate.

The only difference was the level of significance. At 1000, 2000, and 5000 lb per hr, mill speed and discharge were both significant at the 0.1 pct level. At 4000 lb per hr, speed was significant at the 1 pct level and discharge at the 5 pct level.

To aid in interpreting the variance analyses, work index was plotted against feed rate at each speed for both mills on Fig. 7 and against speed at each feed rate for both mills on Fig. 8. The significance of the feed rate–mill discharge interaction can be explained from Fig. 7, which shows that in general the end peripheral discharge mill was more efficient than the overflow mill at low feed rates and less efficient at high feed rates. The curves cross at about 2700 lb per hr at S_{50}, 3700 at S_{60}, 4200 at S_{70}, 3800 at S_{80}, and 2800 at S_{90}. This variation with mill speed causes the significance of the speed–feed rate–mill discharge and mill discharge–speed interactions.

Fig. 8 shows that inclination of the curves relating work index and mill speed gradually changed as feed rate increased, from a positive slope at 1000 lb per hr to a negative slope at 5000 lb per hr (except for the extreme condition of 90 pct of critical). As the feed rate to each type of mill increased, the speed at which the mill should be operated to obtain minimum work index increased. This explains the significance of the feed rate–mill speed interaction.

Fig. 8 also shows that the end peripheral discharge mill was more efficient than the overflow mill at 1000 and 2000 lb per hr at all speeds. At 4000 lb per hr practically identical operation was obtained for both discharges except at the extreme conditions of mill speed, 50 and 90 pct of critical, at which speeds the end peripheral discharge mill was less efficient. At 5000 lb per hr the overflow discharge mill was more efficient at all feed rates. The extreme conditions of speed, however, gave unusually inefficient results for the end peripheral discharge mill at this feed rate. The large differences between the two types of discharge at 50 and 90 pct of critical for feed rates of 4000 and 5000 lb per hr undoubtedly contribute to the significance of the mill discharge–speed and speed–feed rate–mill discharge interactions.

Conclusions

A comparison of the two mills is summarized on Fig. 9 where work index has been plotted against reduction ratio. The points shown are those for the most efficient operating speeds at each feed rate. Log-log paper has been used to space the data conveniently. This figure shows that for a reduction ratio of about 16, efficiency of the two mills was almost equal. At lower reduction ratios the overflow mill was more efficient and at higher reduction ratios the end peripheral discharge was more efficient.

The overflow mill operated most efficiently at a reduction ratio of about 10, at a feed rate of 5000 lb per hr, whereas the end peripheral discharge mill operated most efficiently at a reduction ratio of 25 to 30 and at a feed rate of about 3000 lb per hr (interpolated). At these reduction ratios and respective feed rates, practically the same work index is shown.

References

[1] Will Mitchell, Jr., C. L. Sollenberger, T. G. Kirkland, and B. H. Bergstrom: Analysis of Variables in Rod Milling. *AIME Trans.* October 1954, vol. 199, pp. 1001-1009.

[2] K. A. Brownlee: *Industrial Experimentation.* Chemical Publishing Co., New York, 1949.

Analysis of Roof Bolting Systems Based on Model Studies

Bolting systems can be designed with formulas presented here, which specify bolt spacing, tension, and length that will provide the desired safety factor increase for given thickness and span of roof beds.

by Louis A. Panek

MOST roof bolts are used in mines with bedded roofs, but it has not been determined to what degree thin-bedded roofs can be reinforced by bolting if there is no thick member in which to anchor the bolts, or what function the bolts must perform in such a case. Owing to widespread practice of systematic bolting to support thin-bedded roofs, moreover, it is desirable to design roof-bolting systems on a quantitative basis. Specifically, a solution to the following problem is required: For a roof composed of beds of given thickness and physical properties, what is the optimum length, spacing, orientation, and tightness of bolts consistent with safety and economy? The investigation reviewed here has produced a functional equation to evaluate these variables and establish basic principles of roof bolting.

L. A. PANEK, Member AIME, is Mining Methods Research Engineer, U. S. Bureau of Mines, College Park, Md.

Discussion of this paper, TP 4123A, may be sent (2 copies) to AIME before Dec. 31, 1955. New York Meeting, February 1954.

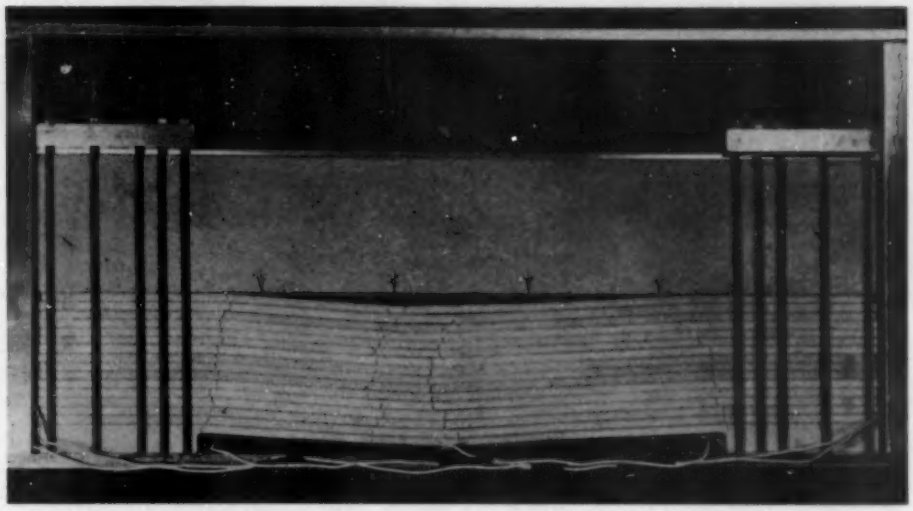


Fig. 1—Model of bedded roof reinforced by four vertical bolts. (Cracks have been penciled for greater visibility.)

Centrifugal testing of roof models was chosen as the experimental method, since it is particularly suited to the study of stratified mine roof.[1] The model shown in Fig. 1 is typical of those tested. The material was Indiana limestone, although the results are independent of the rock type used. In all models the span was 12 in. and the total strata thickness 6 in. The ends were clamped; hence the laminae over the open span acted as roof beds over a mine opening, supported by a pillar at each side. The model was rotated in a centrifuge to induce centrifugal forces proportional to the gravitational forces in the full-sized structure. As strains in the rotating model were measured by means of resistance gages cemented to it at various points, each test provided load vs strain data for one combination of variables. Models were tested to failure only after the required nondestructive tests, usually two dozen or more, were completed. In the model shown in Fig. 1, as well as in all other models employed in this investigation, the bolts were not anchored in the overlying thick member, which may be thought of as the main roof; hence these models correspond to a prototype roof composed of thin beds bolted together to form a more competent unit.

In preliminary tests of laminated roof models similar to that shown in Fig. 1, it was found that bending of the bolted unit was decreased by the use of tensioned roof bolts. (The arrows indicate the positions of the bolts.) For comparison a single-member unit, Fig. 2, was tested with and without bolts; the bolt length equaled the beam thickness. It was found that tensioned roof bolts did not decrease bending of the single-member unit. This can be explained by elementary beam theory, which is accurate enough for the purpose. Vertical lines, drawn on the side of a beam before deflection, remain perpendicular to the neutral axis and therefore rotate as the beam bends, Fig. 3; no rotation occurs at midspan or at the supports. For a series of beams lying one upon the other, the rotations show that slip must occur along the surfaces of contact. Because bolting decreases the bending of laminated roof, the bolts evidently reduce bedding-plane slip. As indicated by laminated beam tests in which bolts were the same diameter as the holes, this reduction results from increase in bedding-plane friction caused by the clamping action of the tensioned bolts rather than from any effect produced by shearing strength of the bolts (considering the action of adjoining bends on a bolt to be that of a giant shears). These tests showed that if the bolts were not tensioned the bending did not decrease and that the greater the bolt tension the greater the decrease in bending. To be effective, therefore, roof bolts must be tensioned when they are installed and must remain under tension thereafter.

If bedding-plane slip could be prevented, a series of beds would bend exactly like a single bed of equivalent thickness. Tests showed, however, that although bedding-plane slip was decreased by bolting it was not prevented, because the bolted unit bent more than a solid bed of equal thickness. Also, there was no single neutral axis for the bolted unit as a whole; rather, each bed exhibited its own neutral axis, the bending strains on the upper surface being opposite in sign to those on the lower surface. Therefore, bolting does not build up a beam equivalent in thickness to that of the series of bolted beds.

In bolted models tested to failure, cracks occurred at the supports and near midspan, Fig. 1, which indicates that stress concentration in the vicinity of a bolt had little if any effect on bending strength, although there was some tendency for a crack to

Fig. 2—Model of a bolted single-member roof.

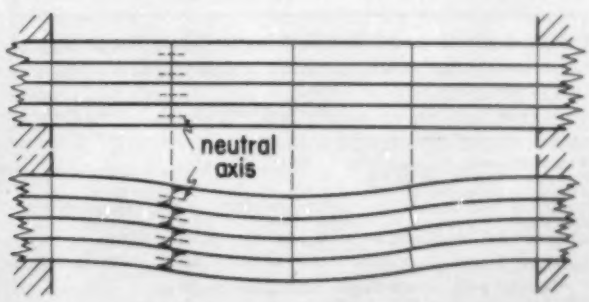


Fig. 3—Flexure of gravity-loaded beams.

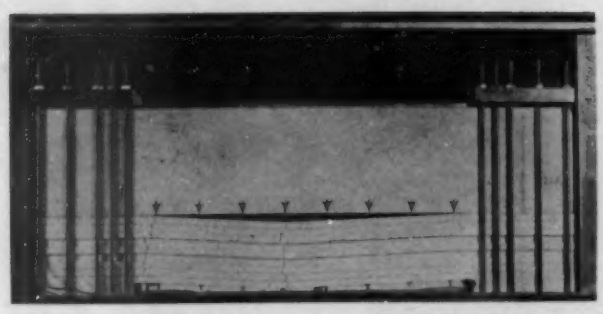


Fig. 4—Model of bedded roof reinforced by eight vertical bolts.

propagate upward along a bolt if the bolt was near midspan or near the rib, the regions of high bending strain. Another example of a crack following a bolt is shown in Fig. 4.

Although the foregoing results aid in interpreting the behavior of bolted roof, it is not possible with this information alone to design an efficient bolting system or to judge the effectiveness of an existing system. Thus it was necessary to consider first what kind of relationship could exist between the variables of the problem. It can be shown from dimensional analysis that it is possible to formulate decrease in roof bending strain due to bolting as an unknown function f of independent ratios formed from the variables:[1]

$$\Delta e_{L/16} = f[\ (wL/E),\ (L/t),\ (L/b),\ (N),\ (P/EL^2),\ (h/t\text{-}1)\ ] \qquad [1]$$

in which $\Delta e_{L/16}$ is the decrease in bending strain of the lowest roof member, due to bolting, measured at a distance of 1/16 span from the rib.* The six

* Accurate measurements could not be obtained at the rib.

quantities in parentheses are the independent ratios, the first two specifying the roof characteristics and the other four the bolting system. The letters w, E, L, and t are, respectively, the unit weight, Young's modulus, span, and bed thickness of the roof rocks; N is the number of bolts per set across the opening; b is the spacing between sets along the opening; P the bolt tension; and h the bolt length (all units in pounds and inches).

The phase of the investigation reported herein was restricted to consideration of steel bolts installed vertically. The N bolts in each set were placed in a straight line across the opening. The model, of width b, approximated a vertical slice through the roof, including one set of bolts and extending half the distance to the adjacent set in each direction. Because each model roof bolt was held by a nut at each end, no anchor slip or loss of tension could occur—the problem of obtaining anchorage in a particular type of rock was not part of this investigation.

Table I. Limits Beyond Which Test Results Should Not Be Applied

Item	General Formula	Example for 16-Ft Span
Maximum span, L	1066 in. (89 ft) *	
Minimum spacing of sets, b	$L/12$	16 in.
Maximum bolts per set, N	12	12
Maximum bolt tension, P	$17 \times 10^{-6} EL^2$	25,000 lb**
Maximum bolt length, h	$3L/8$	72 in.
Minimum bed thickness, t	$L/64$	3 in.

* Assuming $w = 0.09$ lb per cu in., $E = 4 \times 10^6$ psi.
** Assuming $E = 4 \times 10^6$ psi.

To find the exact form of Eq. 1, a factorial experiment[2] was performed in which 92 tests were made on four models to determine $\Delta e_{L/16}$ for at least three values of each of the six independent ratios, including most of the possible combinations. Each test consisted of measuring bending strains at six to eight different loads; more than 600 strain measurements were made. Values of $\Delta e_{L/16}$ were determined by subtracting the strains for bolted roof from the corresponding strains for unbolted roof, measured on the same model. By applying multilinear regression analysis[2] to the test data, the equation for the decrease in bending strain was found to be

$$\Delta e_{L/16} = 0.0858(wL/E)^{2/3}\ (L/t)\ (L/b)^{1/3}\ (N)^{1/3}\ (P/EL^2)^{1/3}\ (h/t\text{-}1)^{1/3}. \qquad [2]$$

The standard error of $\Delta e_{L/16}$ was 12.4×10^{-6} in. per in.; this is a measure of the deviation of the test data from the values given by Eq. 2 and amounts to 18.8 pct of the average determined $\Delta e_{L/16}$.

To avoid extrapolation beyond the range covered by the tests, the limits of applicability of Eq. 2 are summarized in Table I. Because the same material and span were used throughout, w (0.08 lb per cu in.), E (4×10^6 psi), and L were essentially constant; however, owing to the model-prototype relations,[1] the fact that each test consisted of determining $\Delta e_{L/16}$ for a range of loads was equivalent to varying w, E, and L. Within a single model, all beds were of equal thickness. For a roof composed of beds of different thicknesses it may be possible to use the average thickness in Eq. 2; this matter will be considered in the next phase of the investigation. Although the spacing of bolts across the opening is not specified in Eq. 2, an approximately equidistant spacing of the N bolts within the set was used in the tests; other tests showed this to be most satisfacory from an overall point of view. Obviously, no attempt should be made to apply Eq. 2 if t is greater than h, as h/t equals the number of bolted beds.

To find the relation between Eq. 2 and the safety factor, consider the following definitions of the safety factor, SF, for a given roof:

$$\left.\begin{aligned} SF &= \frac{\text{Breaking strain for roof rock}}{e_{max} = e_0} \\ SF' &= \frac{\text{Breaking strain for roof rock}}{e_{max}' = e_0'} \end{aligned}\right\} \qquad [3]$$

in which the unprimed and primed symbols indicate, respectively, the unbolted and bolted conditions, and e_0 is the bending strain at the rib. By definition, let the ratio of these two safety factors be called the reinforcement factor,

$$RF = \frac{SF'}{SF} = \frac{e_0}{e_0'}. \qquad [4]$$

Because the 1/16 span point is so near the rib, the

Table II. Bolt and Steel Requirements for Three Arrangements Each Producing a Reinforcement Factor of 3*

Bolt Length, In.	Bolts Per Set	Spacing of Sets, In.	Per 100 Ft Along Opening	
			Bolts, No.	Steel, Ft
41	4	29	166	664
63	3	29	124	651
48	2	18	132	528

* Roof span = 16 ft, bed thickness = 3 in., unit weight of rock = 0.09 lb per cu in., bolt tension = 10,000 lb. Based on Eqs. 9 and 11.

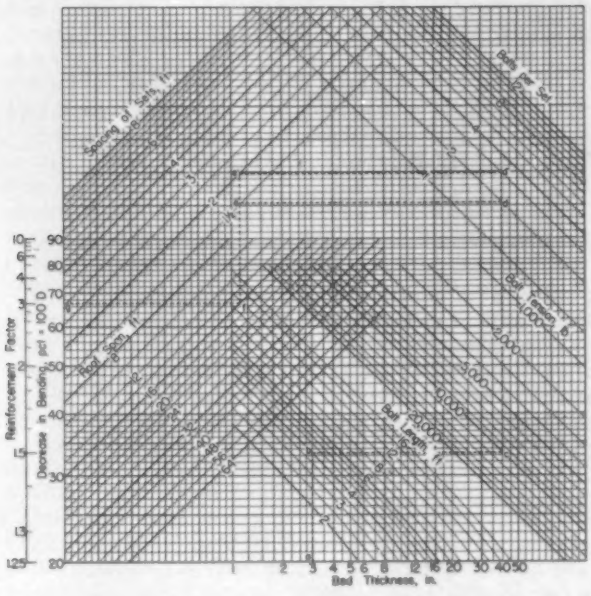


Fig. 5—Roof bolting design chart.

ratio of the bending strain in the unbolted condition to that in the bolted condition is approximately the same at both points, or

$$\frac{e_s}{e_s'} = \frac{e_{L/16}}{e_{L/16}'} . \qquad [5]$$

Substituting Eq. 5 into Eq. 4 and noting that

$$e_{L/16} - e_{L/16}' = \Delta e_{L/16}, \qquad [6]$$

$$RF = \frac{e_{L/16}}{e_{L/16} - \Delta e_{L/16}} = \frac{1}{1 - \dfrac{\Delta e_{L/16}}{e_{L/16}}}, \qquad [7]$$

or, defining $D = \dfrac{\Delta e_{L/16}}{e_{L/16}}$, [8]

$$RF = \frac{1}{1 - D} . \qquad [9]$$

It may be observed that $100D$ is the percentage decrease in bending strain at 1/16 span, due to bolting. For simplicity, the denominator of D was taken to be the theoretical strain given by elementary beam theory,[3] which can be shown to be

$$e_{L/16} = (\text{bending stress at } L/16)/E = 0.324wL^3/Et. \qquad [10]$$

Finally, substituting in Eq. 8 from Eqs. 2 and 10,

$$D = 0.265(bL)^{-1/2}\,[NP(h/t\text{-}1)/w]^{1/2}. \qquad [11]$$

It is now possible to compare the relative merits of two proposed bolting systems; the percentage decrease in bending can be determined from Eq. 11 and the reinforcement factor from Eq. 9, first for one plan and then for the other. The ratio of the two reinforcement factors indicates how much more support is provided by one system than by the other. Similarly, an entire bolting system can be designed from Eqs. 9 and 11, the bolt spacing, tension, and length being adjusted to provide the desired reinforcement factor.

As one would expect, Eq. 11 shows that bending is decreased by increasing bolt tension, number of bolts per set, and bolt length, and by decreasing the spacing of the sets. It is interesting to observe that effectiveness of bolting decreases as the span and thickness of the roof beds increase, which means that the greatest benefits from bolting are obtainable for thin-bedded roof on short spans and implies also that bolts are not an efficient substitute for pillars.

The number of bolts installed per unit length of opening may be decreased either by lengthening the bolts or by reducing the spacing of the sets. Three examples listed in Table II show that an increase in h permits approximately a proportionate reduction in N, hence a proportionate reduction in bolts required per 100 ft of opening, and requires about the same amount of steel (line 1 of Table II vs line 2). On the other hand, a given decrease in b permits more than a proportionate decrease in N, which reduces both the number of bolts and the amount of steel required per 100 ft of opening (line 1 vs line 3) and therefore reduces both the cost of labor and the cost of materials. Judging by the pattern widely used in coal mines, in which bolts are spaced 4 ft apart in both directions, there appears to be an opportunity to reduce the cost of roof bolting, without lowering the safety factor, by decreasing the number of bolts per set (increasing the spacing of bolts across the span) and decreasing the spacing between sets along the length of the opening. The minimum number of bolts per set is best established by experience at any given mine, because it depends on the prevalence of fractures, kettlebottoms, and other local roof imperfections that could cause falls between bolts. A logical procedure would be to decrease the number of bolts per set by steps, each time decreasing spacing b as required by Eq. 11 to maintain a constant reinforcement factor.

Solutions to the design formulas, Eqs. 9 and 11, for the most common ranges of the variables, and for w = 0.09 lb per cu in., may be found by use of a chart, Fig. 5. For example, the broken line *a-b-c-d-e-f-g* shows the bolting system specified by line 3, Table II. The line *d'-e'* shows that 3-bolt sets spaced at 2-ft intervals likewise produce a reinforcement factor of 3, all other quantities remaining constant. The chart may be traversed in either direction as long as the variables are taken in the sequence shown; a line drawn between any pair of variables must of course parallel the corresponding broken line shown on the chart. A few trials will show that for conditions found in most coal mines it is not difficult to obtain a reinforcement factor of 2 to 3; it is difficult to obtain a much greater value.

As shown by Eq. 4, the safety factor for a bolted roof can be calculated only if that for the unbolted roof is known or can be calculated from the strengths and thicknesses of the roof beds. This is to be expected because, for both bolted and unbolted roof, the safety factor depends on the structural properties of the particular roof beds involved. The present investigation makes it possible to calculate the amount of support *provided* by various bolting systems; it does not indicate the amount of support *needed*. Nevertheless, if at a given mine it is decided that the bolting system in use does not provide enough support, Eqs. 9 and 11 or Fig. 5 can be used to determine the present reinforcement factor and the most effective means of increasing it.

References

[1] L. A. Panek: Centrifugal Testing Apparatus for Mine-Structure Stress Analysis. U. S. Bur. of Mines, *R. I. 4883*, 1952.
[2] D. S. Villars: Statistical Design and Analysis of Experiments for Development Research. W. C. Brown Co., Dubuque, Iowa, 1951.
[3] S. Timoshenko: Strength of Materials, Part I. D. Van Nostrand Co., 1946.

Quartz Flotation with Cationic Collectors

By streaming potential techniques, the zeta potential of quartz has been measured as a function of the concentration of dodecylammonium salts at different pH values. These experiments indicate that adsorption of dodecylammonium ions takes place as individual aminium ions until a certain critical concentration is reached in the double layer, at which point the adsorbed collector ions begin to associate into patches of ions, called hemimicelles. Because of its effect on the surface potential of quartz, pH controls the adsorption of dodecylammonium ions. The value of cooperating agents and nonionized constituents of flotation systems is discussed.

by A. M. Gaudin and D. W. Fuerstenau

A PREVIOUS investigation[1] of the role of pH in the flotation of quartz with anionic collectors is here extended to an inquiry of how the cationic collector, dodecylammonium acetate, is adsorbed at the quartz-solution interface. The equilibrium amount of this collector adsorbed by quartz has already been measured as a function of concentration and pH.[2, 3] The weight of prior evidence has suggested that two mechanisms are involved in the adsorption of this collector by quartz, but with existing adsorption measurements alone it is not possible to determine what the mechanisms are. Gaudin and Bloecher[3] postulated that a polymolecular adsorption coating begins to form before the first monolayer has been completed. Gaudin and Morrow[4] indicated that a similar situation might exist in the film of dodecylammonium ions on hematite. A study of electrokinetic potentials at the quartz-solution interface provides some detail toward a fuller understanding of the adsorption mechanism.

A. M. GAUDIN, Member AIME, and D. W. FUERSTENAU, Junior Member AIME, are, respectively, Richards Professor of Mineral Engineering and Assistant Professor of Mineral Engineering, Massachusetts Institute of Technology.

Discussion of this paper, TP 4104B, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, April 11, 1955. Experimental data taken from a thesis submitted by D. W. Fuerstenau in partial fulfillment of the requirements for the degree of Doctor of Science at Massachusetts Institute of Technology.

Experimental Results

The zeta potential at the quartz-solution interface was calculated from streaming potential data measured with the apparatus described in detail in a thesis by Fuerstenau[5] and briefly in a paper by Gaudin and Fuerstenau.[1] The quartz used in these experiments was a 48/65-mesh fraction prepared in the manner described previously.[1]

Zeta potential of quartz was obtained for various amounts of the amine salt at pH 4, 7, 10, 11. In

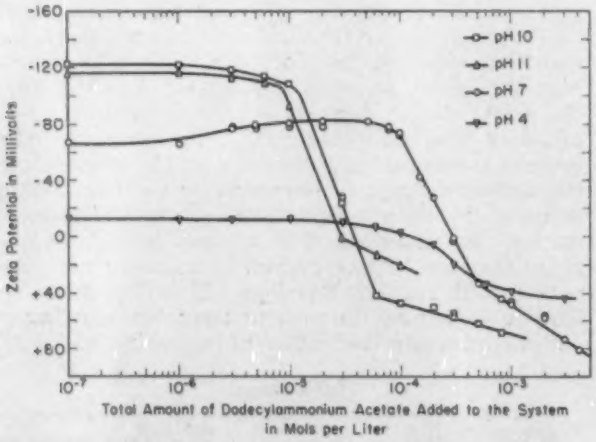


Fig. 1—Zeta potential of quartz in solutions of dodecylammonium acetate at four different pH values.

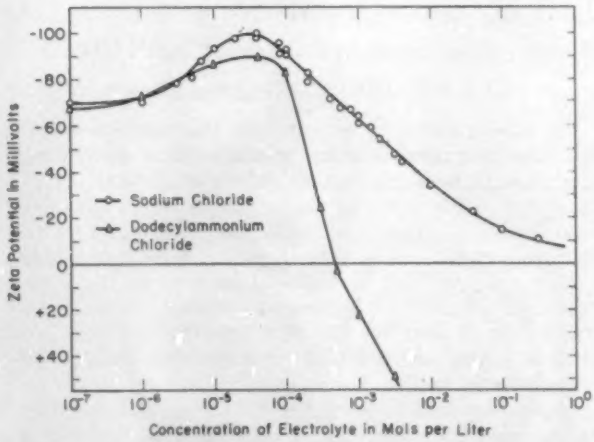


Fig. 2—Zeta potential of quartz in solutions of dodecylammonium chloride and sodium chloride.

Fig. 1 the experimental values of ζ are plotted as a function of the total amount of dodecylammonium acetate in the system.

Each of the four graphs consists of three parts: 1) in the low concentration range, a portion where ζ changes very little with concentration, 2) a part where the slope of the ζ — log — C curve changes sharply and the sign of ζ passes from negative to positive, and 3) at relatively high collector concentrations, a part in which the slope of the curve is greatly reduced. The concentration at which ζ decreases abruptly in absolute magnitude is shifted to lower concentrations of collector as the pH is increased. In solutions at pH 4 in which the value of ζ at infinite dilution of collector is only −12 mv, the change in ζ is much less pronounced than at higher pH values.

Measurements were made to compare the action of the cationic collector (as the chloride salt) with sodium chloride at neutral pH. The experimental data are plotted in Fig. 2. These data show that in dilute solutions dodecylammonium ions behave like sodium ions, but that at higher concentrations the adsorption mechanisms must differ. There is a slight difference between dodecylammonium acetate and dodecylammonium chloride. This may be attributable to the greater hydrolysis of the acetate. For a discussion about the rise in the zeta potential in dilute solutions as calculated from streaming potential data, the reader is referred to the authors' previous paper.[1]

Fig. 1 shows that in alkaline solutions dodecylammonium ions abruptly reduce the value of ζ at concentrations well below that which increase the ionic strength of the solutions. To test whether the reduction of ζ in dodecylammonium acetate solutions results from compression of the double layer or from some other phenomenon, experiments were carried out to measure streaming potentials of quartz in solutions containing a fixed amount of dodecylammonium acetate with varying amounts of sodium chloride to compress the double layer. In one series of experiments the collector concentration was maintained at 10^{-4} M (ζ is −78 mv) and in the other series the concentration was maintained at 5×10^{-4} M (ζ is +36 mv). Thus the effect of ionic strength on the zeta potential of quartz in solutions of surface-active electrolytes was tested in one case with the zeta potential negative and in the other, with the positive.

The experimental data are plotted in Fig. 3. Earlier work showed that the addition of an indifferent electrolyte, such as NaCl, to a solution does not change the zeta potential of quartz until the total ionic strength of the solution is changed.[1] The effect of compression of the double layer then is to reduce the absolute value of ζ. Fig. 3 shows that the addition of NaCl to solutions containing a fixed amount of collector causes merely a change in absolute value of ζ, and then only if the ionic concentration is sufficiently changed. The abrupt change of ζ with increasing dodecylammonium acetate concentration therefore does not result from compression of the double layer but must result from some other phenomenon. It may therefore be concluded that although in dilute solution dodecylammonium ions may be held to the surface by electrostatic attraction for the negative surface charge (as are sodium ions), at higher concentrations there must intervene a new mechanism specific to the hydrocarbon-bearing ion. To understand how dodecylammonium ions function at the quartz surface, it is useful to consider first how these ions behave in solution.

Attributes of Aqueous Solutions of Dodecylammonium Acetate: The chemical formula for dodecylamine is $CH_3(CH_2)_{11}NH_2$, or RNH_2. In water the amine ionizes in the following manner, Eq. 1:[6]

$$RNH_2 + H_2O \rightleftharpoons RNH_3^+ + OH^-; \quad K = 4.3 \times 10^{-4} \qquad [1]$$

Solubility of the undissociated amine has been found to be 2×10^{-5} mols per liter.[3]

Since dodecylamine salts are salts of a weak base they are hydrolyzed in solution, a substantial proportion of the hydrocarbon-bearing groups being in the form of the free amine. This is especially true in alkaline solution, but the effect is negligible in neutral or acid solutions. In view of the electrical nature of the measurements made and interpretations sought it is desirable to consider the data of Fig. 1 when expressed in terms of concentration of dodecylammonium ions. The redrawn data are shown in Fig. 4, together with measurements for sodium chloride added for comparative purposes.

Water is known to have tremendous affinity for itself and no particular attraction for hydrocarbons; consequently, hydrocarbon chains seek to escape from water by associating with each other. This is

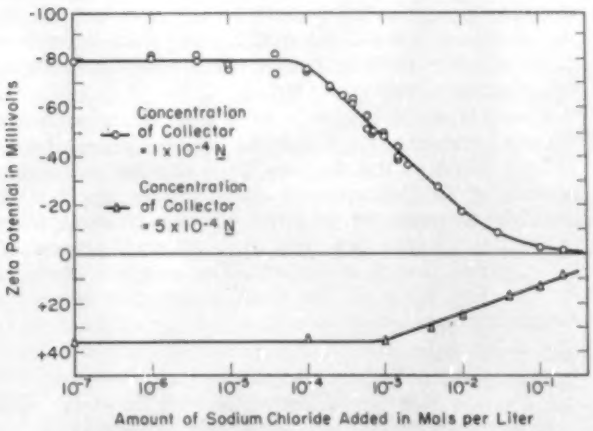


Fig. 3—Effect of sodium chloride on the zeta potential of quartz in solutions of dodecylammonium acetate.

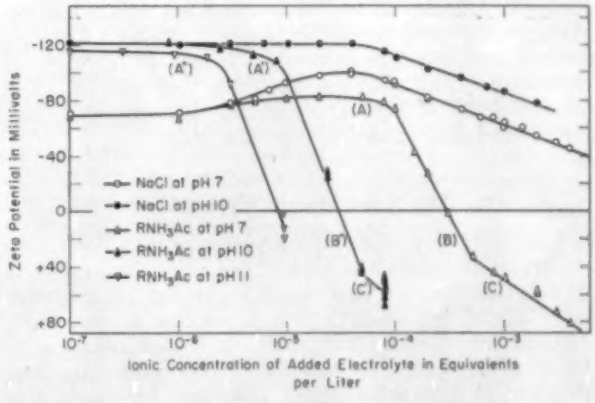


Fig. 4—Zeta potential of quartz in solutions of dodecylammonium acetate and sodium chloride at several different pH values.

true also for the hydrocarbon part of an amine in water, but this is counteracted by the water avidity of the ammonium group, $-NH_3^+$, which occurs at what may be called the head of the aminium ion.

In dilute solutions dodecylammonium acetate behaves as an ordinary strong electrolyte, but at a certain concentration there is a marked change in physical properties of the solutions, e.g., in equivalent conductance, transport number, freezing-point lowering, and viscosity. To account for these phenomena, McBain introduced the concept of micelles, which are aggregates of paraffin-chained ions.[7] Micelles form only at high concentrations, e.g., in the case of dodecylammonium acetate above 0.013 *M*.[8] It is believed that the ionic heads of the constituent ions of the micelle are in contact with water, whereas the nonpolar groups turn away from it and are in contact with each other.

1) Micelle Size: To aggregate ions into a micelle, work must be done to bring the charged heads close to each other, but potential energy is gained, since the hydrocarbon chains in the micelles can be regarded as having left the aqueous medium. Hence, the total number of ions in the micelle structure must be determined by the equilibrium between the repulsive long-range coulombic forces and the short-range attractive London-van der Waals forces between hydrocarbon chains. According to calculations by Debye[9] the maximum number of ions in a dodecylammonium micelle is 40, and according to his experiments, using light scattering, the number is 66. In ionic solutions of higher ionic strength, the micelles are somewhat larger because of the reduction in charge brought about by the presence of counterions in the double layer about the micelle. Since the decrease in free energy by the transfer of hydrocarbon chain from water to the micelle is 1300 calories per mol per CH_2 group, and since the repulsive energy is about the same, micelles of homologous compounds must grow larger with increasing chain length. Debye and Anacker estimate that the micelle of the 10-carbon n-alkyltrimethyl-ammonium bromide contains approximately 36 ions per micelle and that of the 14-carbon n-alkyl salt 75.[9]

2) Micelle Shape: There has been much discussion regarding the shape of micelles. McBain has proposed that micelles are either spherical or lamellar.[9] Hartley believes they are spherical only.[10] On the other hand, German workers, using X-rays, seem to have proved the existence of the lamellar type.[11] Harkins' more recent work (with soap) offers a cylindrical model because oil solubilization data do not agree with the lamellar model.[12] Finally, Debye and Anacker showed in 1951 that micelles of n-hexadecyltrimethyl-ammonium bromide in 0.178 *M* and 0.233 *M* KBr are rod-like (elongated cylinders) and not spherical nor disk-like.[13]

The Hemi-Micelle Hypothesis

In dilute solutions dodecylammonium ions are adsorbed as individual ions,[3, 4] but once the adsorbed dodecylammonium ions reach a concentration at the solid-liquid interface which is similar to the bulk critical micelle concentration, is it not reasonable to suppose that the adsorbed ions associate into patches at the solid-liquid interface in much the same way they associate to micelles in the bulk solution? The forces causing ionic association at the surface will be the same as those operating in the bulk. Because of the high surface charge, the dodecylammonium ions must necessarily be oriented with the charged heads towards the surface and with the tails sticking out into the liquid. The associative van der Waals forces in the hydrocarbon chains will be supplemented and reinforced by the coulombic forces of attraction between collector cations and negative sites on the mineral surface. If the adsorbed ions associate tightly with the heads oriented towards the surface and with the tails sticking out into the liquid, a minimum surface area of the hydrocarbon chain will be in contact with water. Because of the proposed appearance of such absorbed collector ions, the authors propose to call these patches of associated ions *hemi-micelles*.

Streaming potential experiments vindicate the hemi-micelle hypothesis. It has been shown that monovalent sodium ions cannot change the sign of ζ but merely reduce its value to the vanishing point at very high concentrations, whereas multivalent inorganic ions are able to change the sign of ζ at moderate concentrations.[3] Fig. 4 shows identity in behavior of RNH_3^+ and Na^+ at very low concentrations of these ions. At these low concentrations dodecylammonium ions must function as simple monovalent counter ions. Fig. 4 shows also that at a moderate concentration for RNH_3^+ there is a sharp break in the ζ — log — C curve. This change accords with other zeta potential data[3] only if a highly charged cation adsorbs at the surface when the critical concentration is exceeded. This highly charged cation (perhaps containing also some associated uncharged molecules, as discussed below) is what the authors call the *hemi-micelle*.

The ξ—log—C curves for amines are further characterized by a second sharp change in slope. This occurs at higher concentrations. However, the second break in the curve at neutral pH corresponds roughly to the concentration at which deBruyn found monolayer coverage.[3] If the second layer of a multilayer adsorbate is held by van der Waals' attraction between hydrocarbon chains, collector ions in the second layer must be in opposite orientation. Adsorption of a second layer of collector ions in reverse orientation was postulated several years ago by Arbiter, Kellogg, and Taggart,[14] by Taggart and Arbiter,[15] and by Rogers, Sutherland, Wark, and Wark.[16] Collector ions will be held strongly in the first layer because of their affinity for the negative sites at the surface, but once the first layer is filled, the adsorption is necessarily less because this specific affinity for the surface no longer exists. Hence the zeta potential of quartz, which is measured by shear between the solid and liquid, would increase more slowly with concentration after monolayer coverage has been exceeded.

There is some evidence of a quantitative nature for the hemi-micelle. Since the concentration of ions at any point in the double layer can be calculated according to Boltzmann's distribution law,[17] it is possible to evaluate whether the ion concentration in the double layer exceeds that, which if present in bulk, gives rise to micelles. The concentration of ions at any point in the double layer is given by Boltzmann's relation, Eq. 2:

$$n = n_0 \exp\left(\frac{-ve\Psi}{kT}\right)^* \qquad [2]$$

* $\exp(a) = e^a$.

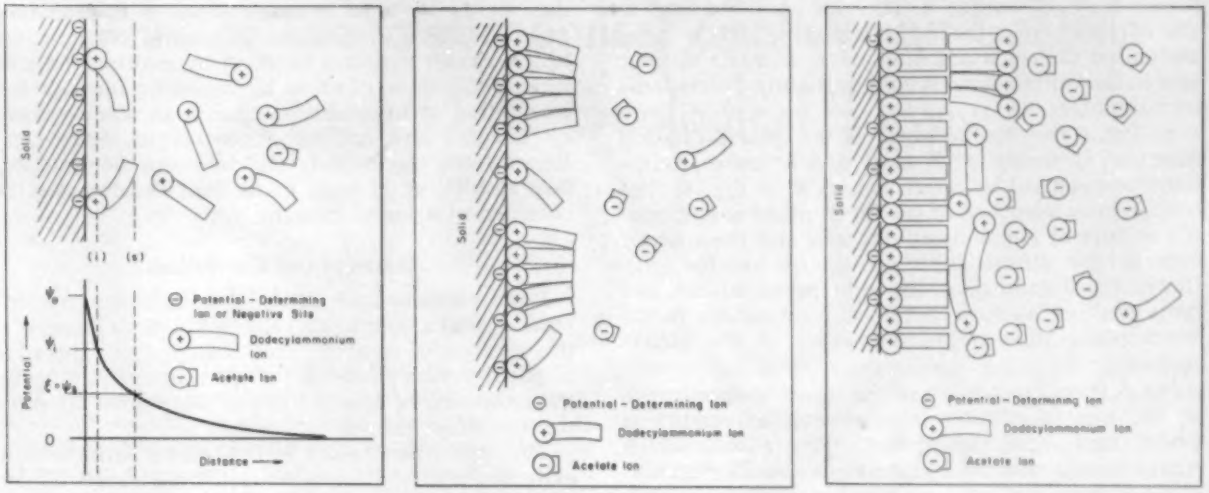


Fig. 5 (left)—Structure of the double layer and the distribution of potential in the double layer under conditions below those under which hemi-micelles form. Fig. 6 (center)—Structure of the electrical double layer under conditions which give rise to hemi-micelles at the quartz-solution interface in dodecylammonium acetate solutions. Fig. 7 (right)—Multilayer adsorption at the quartz-solution interface.

where n is the concentration of ions in the double layer at any given point, n_o is the concentration of ions of the same species in the bulk solution, k is Boltzmann's universal constant, T is the absolute temperature in degrees Kelvin, v is the valency of the ions, e is the charge of the electron, and Ψ is the potential at the point under consideration in the double layer. The value of $\frac{ve\Psi}{kT}$ is about 1 if Ψ is 25 mv, v is 1, and T is 25°C.

To ascertain the magnitude of Ψ_i at the plane where the adsorbed dodecylammonium ions lie, consider the present concepts of the quartz-solution interface. It was shown that hydrogen and hydroxyl ions are potential-determining ions for quartz[3] and by definition the magnitude of the surface potential Ψ_o is controlled by the pH of the bulk solution. The total double layer potential Ψ_o is given by[10]

$$\Psi_o = \frac{kT}{ve} \ln \frac{C^+}{C_o^+} = -\frac{kT}{ve} \ln \frac{C^-}{C_o^-} \quad [3]$$

where C^+ and C^- are the concentrations of the potential-determining ions in the solution, and C_o^+ and C_o^- are the concentrations of these ions at the zero point of charge. Since the zero point of charge of quartz[3] occurs at pH 3.7, $C_o^+ = 2 \times 10^{-4}$,and the total double layer potential, Ψ_o, of quartz at pH 7 should be about −190 mv.

For quartz in solutions containing 10^{-4} mols per liter of dodecylammonium acetate at pH 7 (*A*, Fig. 4), the structure of the electrical double layer and the distribution of potential in the double layer is given schematically in Fig. 5. The surface potential or total double layer potential is represented by Ψ_o in Fig. 5. It is known that the slipping plane must occur outside the hydrocarbon chains of the most closely-held dodecylammonium ions, and since the zeta potential is the potential located at the slipping plane, it must be the potential at the plane s in Fig. 5. However, the work necessary to bring the charged head of a collector ion to the surface (the plane i in Fig. 4) is $ve\Psi_i$. The value of Ψ_o is about −190 mv (Eq. 3) and experimentally the value of $\zeta = \Psi_s$ was found to be about −80 mv. According to Fig. 5, it is known that the value of Ψ_i must lie between the surface potential Ψ_o and the zeta potential ζ. For calculations, Ψ_i will be assigned a value halfway between Ψ_o and ζ, or −135 mv. Using the Boltzmann equation for conditions at which the slope of the ξ—log—C curve (Fig. 4) abruptly breaks at pH 7, the concentration of dodecylammonium ions next to the surface, n, is (Eq. 4):

$$n = n_o \exp\left(\frac{-ve\Psi_i}{kT}\right) = 1.0 \times 10^{-4}\, e^{3.4} = 0.020\ M. \quad [4]$$

This calculation shows that close to the surface the concentration of collector ions exceeds slightly the bulk critical micelle concentration, 0.013,[5] even though the bulk concentration of collector is only 1×10^{-4} *M*. This is one line of evidence which in the authors' opinion substantiates the hemi-micelle hypothesis. It should be pointed out that the surface concentration of dodecylammonium at which association between the hydrocarbon chains takes place probably differs from the bulk critical micelle concentration.

Eq. 4 shows that the concentration of dodecylammonium ions close to the surface depends on the bulk concentration of collector (n_o term and the ionization constant) and the pH of the solution (Ψ term and Eq. 3). Since the surface potential of quartz is determined by the concentration of hydrogen or hydroxyl ions in solution, increasing the pH of the solution increases the negative value of Ψ_o and therefore the ratio of n to n_o (Eq. 2). This suggests that hemi-micelles can form at a lower bulk RNH_3^+ concentration. Fig. 4 is in accord with this conclusion.

The authors' idea of the structure of the electrical double layer at the quartz-solution interface is presented schematically in Figs. 5, 6, and 7. In Fig. 5 the double layer at the quartz-solution interface is shown as it may appear if the solution concentration is dilute enough so that association of the collector ions at the interface has not taken place. This would correspond to any concentration below

points *A*, *A'*, *A"* in Fig. 4. The ions adsorbed next to the surface, or in the Stern plane, would be nonassociated dodecylammonium ions, and the counter ions in the diffuse layer would be mainly dodecylammonium ions.

In Fig. 6 the double layer at the quartz-solution interface is shown as it may appear under conditions represented by points *B* and *B'* in Fig. 4. The counter ions adsorbed in the Stern plane would consist mainly of hemi-micellular ions and the counter ions in the diffuse layer would be acetate ions. Under these conditions the zeta potential can become positive because there are more cations in the Stern plane than negative charges at the quartz surface.

Fig. 7 is an illustration of the possible appearance of the quartz-solution interface under conditions where multilayer adsorption takes place, which would be represented by points *C* and *C'*, Fig. 4.

Evidence of Hemi-Micelle Formation in Other Flotation and Surface Phenomena

If the long-chained dodecylammonium ions aggregate at the quartz-solution interface to form hemi-micelles, this should certainly affect other flotation phenomena. For example, ion aggregation should increase the contact angle because of the more closely-packed hydrocarbon chains. Thus, if the pH of a solution of dodecylammonium acetate containing less than 1×10^{-4} *M* is increased, at a certain pH, the contact angle should rise sharply. Morrow's experimental data substantiate this.[4]

Furthermore, after hemi-micelle formation, collector adsorption is enhanced by van der Waals' attraction between hydrocarbon chains. Thus measurement of adsorption of collector at the quartz-solution interface as a function of concentration should show that at a certain concentration of collector in solution, the adsorption increases more rapidly than expected. Bloecher,[2] deBruyn,[3] and Morrow[4] found this to be true.

In this paper the association of collector ions at the solid-liquid interface has been discussed, but evidence of agglomeration of nonpolar hydrocarbon chains exists in other surface phenomena. For example, the formation of *hemi-micelles* at the solid-solution interface is analogous to the formation of patches of molecules in an oleic acid monolayer at the air-solution interface—the "intermediate liquid film" of Harkins.[12] Further evidence of interaction between hydrocarbon chains of heteropolar ions and molecules has been demonstrated by Schulman and Leja.[19] They showed that association between collector ions and frother molecules takes place not only at the air-liquid interface but also at the solid-liquid interface.

If hydrocarbon chains associate at the mineral-solution interface even though the collector ions are charged, it would be expected that uncharged hydrocarbon would interact by van der Waals' attraction with adsorbed collector chains even more since the repulsive forces would not be operating. In alkaline solutions where the concentration of dissolved free amine may equal or exceed the concentration of dissolved aminium ion, the hemi-micelle may well include a substantial proportion of free amine, even though the attraction of the negatively charged surface for the aminium cation is not here operative to bring the free amine into the region of high concentration of hydrocarbon groups. The mill practice of adding oil extender to the circuit may aid flotation by making the surface of the mineral more hydrophobic through this interaction of hydrocarbon chains, as was proposed by Taggart and Arbiter a number of years ago.[20] Hence from theoretical considerations better flotation results, or at least equivalent results, may be obtained at a lower reagent cost.

Summary and Conclusions

Dodecylammonium salts in submicellar concentration make enormous electrokinetic changes at the surface of quartz. The change from negative to positive zeta potential for the mineral establishes the existence of specific cation adsorption in some concentration ranges.

The adsorption seems to take place as individual aminium ions until a certain critical concentration is reached in the double layer. At this critical concentration it seems that the adsorbed ions begin to associate into hemi-micelles adjacent to the surface and oriented. This phenomenon would be similar to that leading to the formation of micelles in bulk solutions. The hemi-micelles can be considered as giant polyvalent cations, polymers of the unassociated aminium ions, possibly combined with some amine molecules too.

The hemi-micelle hypothesis leads to interesting speculations concerning the value of cooperating collectors, and the part of nonionized collecting constituents of flotation systems. Interesting parallels to the properties of gas-liquid interfaces of aqueous solutions are indicated.

Acknowledgments

The authors wish to acknowledge the help given them by their associates at the Massachusetts Institute of Technology, especially by J. Th. G. Overbeek, presently of the University of Utrecht, Netherlands, and P. L. deBruyn. This work was carried out by the generous support of the U. S. Atomic Energy Commission.

High-purity dodecylammonium acetate was supplied through the courtesy of H. J. Harwood of Armour & Co., Chicago.

References

[1] A. M. Gaudin and D. W. Fuerstenau: *AIME Trans.*, 1955, vol. 202, p. 66.
[2] A. M. Gaudin and F. W. Bloecher: *AIME Trans.*, 1950, vol. 187, p. 499.
[3] P. L. de Bruyn: *AIME Trans.*, 1955, vol. 202, p. 291.
[4] A. M. Gaudin and J. G. Morrow: *AIME Trans.*, vol. 199, p. 1196.
[5] D. W. Fuerstenau: Streaming Potential Studies on Quartz. Sc.D. thesis, Massachusetts Institute of Technology, 1953.
[6] A. W. Ralston: *Fatty Acids and Their Derivatives*, chap. 8. John Wiley and Sons, New York, 1948.
[7] J. W. McBain: *Trans. Faraday Society*, 1913, p. 99.
[8] P. Debye: Journal of Physical and Colloid Chemistry, 1949, vol. 53, p. 1.
[9] J. W. McBain: *Colloid Chemistry*, vol. 5, ed. Jerome Alexander. Reinhold Publishing Corp., New York, 1944.
[10] G. S. Hartley: *Kolloid-Zeit.*, 1939, vol. 88, p. 22.
[11] H. R. Kruyt: *Colloid Science*, vol. 2, chap. 14. Elsevier Publishing Co. Inc., 1949.
[12] W. D. Harkins: *The Physical Chemistry of Surface Films*, chaps. 2 and 4. Reinhold Publishing Corp., New York, 1952.
[13] P. Debye and E. W. Anacker: *Journal of Physical and Colloid Chemistry*, 1951, vol. 55, p. 644.
[14] N. Arbiter, H. H. Kellogg, and A. F. Taggart: *AIME Trans.*, 1943, vol. 153, p. 517.
[15] A. F. Taggart and N. Arbiter: *AIME Trans.*, 1946, vol. 169, p. 266.
[16] J. Rogers, K. L. Sutherland, E. E. Wark, and I. W. Wark: *AIME Trans.*, 1946, vol. 169, p. 287.
[17] S. Glasstone: *Textbook of Physical Chemistry*, p. 265. D. Van Nostrand Co., New York, 1940.
[18] H. R. Kruyt: *Colloid Science*, vol. 1, chap. 6. Elsevier Publishing Co., Inc., 1949.
[19] J. Leja and J. H. Schulman: *AIME Trans.*, 1954, vol. 199, p. 221.
[20] A. F. Taggart and N. Arbiter: *AIME Trans.*, 1943, vol. 153, p. 500.

Work of the Geochemical Exploration Section Of the U. S. Geological Survey

by T. S. Lovering

GEOCHEMICAL prospecting extends the age-old method of searching out lodes with a gold pan and rationalizes the prospector's hunch that certain plants are associated with ore. It uses sensitive but cheap and rapid analytical methods to find the diagnostic chemical variations related to hidden mineral deposits. Exploration geologists can gain tremendous assistance from this new tool, although its optimum use is not simple. To bring out the geochemical pattern that reveals the presence of a hidden ore deposit with a minimum number of samples requires a combination of shrewdness, chemical knowledge, and exploration geology.

The use of sensitive analytical methods for prospecting had its start in the 1930's in northern Europe, where Scandinavian and Russian geologists had some success in these early efforts. Very little geochemical prospecting was carried on in the United States at this time, and no sustained interest was manifest until the close of World War II, when geochemical investigations were started by the Mineral Deposits Branch of the U. S. Geological Survey. The purpose of these investigations was to apply geochemical principles and techniques to surface exploration for mineral deposits. Both the research on analytical methods and the routine trace analyses for field investigations were at first conducted by a single group, but it later became apparent that the trace analyses could be done by men of less experience than that required for successful research on methods. For the past several years there have been two groups of chemists, and although their functions overlap, three of the chemists are chiefly concerned with research, while four to six other men make the trace analyses for field projects.

The chemical investigations, as well as the field projects of the Geochemical Exploration Section, concern only those phases of the subject that are appropriate to a government organization; every effort is made to help private industry, but not to compete with it, in finding orebodies. The chief aim of the Section, therefore, is to develop new analytical techniques and publish the results promptly, to carry out field investigations of the fundamental principles of geochemical dispersion, and to field test promising techniques under controlled conditions.

Some routine geochemical exploration work is carried on in connection with DMEA loans, and in district studies where the project chief wishes geochemical information on certain areas for his report. It should be emphasized, however, that geologists of the Geochemical Exploration Section are primarily concerned with fundamental principles underlying the distribution, migration, and concentration of elements in the earth's crust.

To facilitate the use of geochemical methods the USGS has published much information on its methods of analysis and has provided opportunities from time to time for qualified professional personnel to study these methods, to work in the USGS laboratory, or to attend demonstrations of the analytical techniques at the Denver Federal Center.

Typical of the research carried on are the problems now being investigated:

1) Development of rapid and sensitive analytical methods suitable to the determination of traces of metals and other minor elements in various materials, such as rock, soils, plants, and water. At the present time attention is being concentrated on U, Bi, Cr, and Hg, and satisfactory rapid trace analytical methods are virtually perfected for U and Bi. Good methods are also available for: Cu, Zn, Pb, Ni, Co, As, Sb, W, Mo, Ag, Nb, Ge, V, Ti, Fe, Mn, S, and P.

2) The relation of geochemical anomalies in plant materials to the geochemical distribution of elements in soils surrounding the plant.

3) A study of the dispersion halos in transported sedimentary cover such as glacial drift and alluvium over known orebodies.

4) A study of the behavior of ore metals in the weathering cycle.

5) A study of the behavior of the ore metals during magmatic differentiation. This requires a study of the distribution of minor metals in fresh igneous rocks and their component minerals in a well established differentiation series and in adjacent country rock.

6) A study of the dispersion of metals in primary halos in the wall rock surrounding orebodies.

7) Regional and local studies of the metal content of surface and groundwater in mineralized and barren areas.

Many field projects of the Mineral Deposits Branch also require the services of USGS chemists during their investigation of the geochemical environment of ore deposits.

From the work that has been done certain general principles have emerged. Concentrations of an element that are above the general or background value of barren material are called *positive geochemical anomalies* or simply *an anomaly*, whereas values less than background are called *negative anomalies*. The anomalies most commonly investigated in geochemical prospecting are those formed at the earth's surface by agents of weathering, erosion, or surficial transportation, but more and more attention is being given to primary anomalies found

T. S. LOVERING is Chief, Geochemical Exploration Section, U. S. Geological Survey, Denver, Colo.

Discussion on this paper, TP 4043L, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, Jan. 31, 1955. Chicago Meeting, February 1955.

in bedrock, such as those related to hydrothermal alteration and the ore depositing processes.

There may be a marked variation in the background of an element within certain broad regions that may be considered metallogenetic provinces. Intrusive rocks within regions where tin veins occur commonly have a higher background of tin than similar rocks in other areas; high cobalt has been found in country rock miles away from known ores in Idaho; high antimony is characteristic of the country rock in Alaskan antimony districts. It has become evident, therefore, that chemical studies may provide regional as well as local guides for ore.

As recently stated by Ahrens (1954) the general distribution of trace elements in common rock is approximately log normal. In harmony with Ahrens' conclusions the USGS has found in studying patterns of anomalous values that significance depends more upon relative differences than upon arithmetric differences. The USGS takes the threshold of significance to be approximately twice the value for background in most instances. It has also found that the significance of the geochemical anomaly is best expressed by use of geometric ratios: in contouring geochemical results the different contours commonly represent 2, 4, 8, 16, and 32 times the background value rather than 2, 3, 4, 5, and 6 times the background.

Any study of a primary anomaly should be based on a good knowledge of the geology of the mineral deposits. A primary halo resulting from hydrothermal alteration may be either on the outlet sides of a blind orebody or on the inlet side of an eroded orebody, and the solutions creating it may have been moving upward at a decided angle. The resulting anomaly therefore may not be directly over the ore and may be offset a substantial distance from a vertical position above the blind mineral deposit. In studying primary halos it is of great importance to establish the angle or rake of the anomaly at depth, the third dimension of the geochemical anomaly.

Interpretation of geochemical anomalies always depends upon local conditions. In an unexplored area first priority for physical exploration will usually be given to those anomalies that show high contrast to background, are relatively homogeneous, and have substantial areal extent. Nevertheless, the geochemical prospector should always realize that he is far more likely to hit noncommercial mineralization than a bonanza. Although a geochemical anomaly that runs 2500 ppm of lead in contrast to a background of 20 ppm is impressive, it should not be forgotten in the enthusiasm of the moment that the high-grade anomaly still is only 0.25 pct lead and may represent concentration over mineralized ground that carries even less.

The likelihood of finding a profitable orebody is probably analogous to that of finding a productive ore district. Some idea of a statistical probability of doing this is given by the figures T. B. Nolan presented in his presidential address of 1950 before the Society of Economic Geologists. The districts within a radius of 200 miles of the Hoover Dam number 285 and are distributed through 125,000 sq miles of territory, or approximately one district for every 440 sq miles. When plotted as a graph according to orders of magnitude of production, beginning with zero to 10,000 and ending with more than 100 million dollars, the number of districts in each category are as follows: 123, 77, 40, 34, 9, 2. This approximates an exponential curve corresponding to the squares of consecutive odd numbers 11, 9, 7, 5, 3, 1. It seems reasonable that in any population of ore deposits or groups of ore deposits, such as comprise districts, there will be a similar exponential variation and that a dozen or more noncommercial deposits will be found for every one of major importance. It is in harmony with this assumption that the well-known statistical studies of Lahee on oil discoveries show that only one wildcat in about nine brings in a new oil field, even though the work is based on geologic and geophysical advice.

USGS work on primary halos has shown that an anomaly with good contrast may be obtained in an altered but barren extrusive rock 350 to 500 ft above horizontal pipe-like orebodies in an underlying limestone where there is minor premineral fracturing in the extrusive rock and limestone. In the walls of orebodies in unfractured limestone, however, the heavy metals move only a short distance, commonly from 10 to 20 ft, beyond the sharp edge of the ore. In one place where sampling was carried on in a crosscut, a sharp rise in the lead value at the face led to the conclusion that an orebody must be nearby, although there was no other indication. The crosscut was extended later and the edge of a previously unsuspected orebody was found about 12 ft ahead. More than 12,000 tons of ore averaging 6 pct lead, 7 pct zinc, and 7 oz of silver were taken from this body, the presence of which was indicated by geochemical sampling.

Anomalies of surficial origin—secondary anomalies—include most of the discoveries credited to successful geochemical prospecting. Such anomalies result from the weathering of rocks and ores *in situ* and occur in the material dispersed from an ore deposit by glacial ice, moving water, or by slide and creep (colluvium). In general gold, lead, tin, iron, manganese, arsenic, and antimony are relatively immobile and tend to concentrate in residual soil; uranium, cobalt, nickel, and zinc are much more mobile and are usually impoverished in gossans. Copper, silver, molybdenum, and tungsten are erratic in their behavior and in some areas are enriched and in others leached. Many of the more mobile metals are fixed in part by clays in the soil at no great distance from the weathering orebodies and tend to form a broader geochemical anomaly than do the immobile metals. Although much early geochemical work was restricted to areas of residual soil, recent work has indicated the possibility of using it successfully in colluvium covering subcutcrops of ore.

In the Blackbird cobalt district of central Idaho, which was investigated by the Geological Survey, geochemical anomalies show maximum arsenic and cobalt content of about 1000 and 300 ppm, respectively, as compared with background values of 10 and 30 ppm. The contrast for arsenic which is associated with the cobalt ore is 100 to 1, but the cobalt contrast itself is only about 10 to 1, and as a result the anomaly expressed by the arsenic pattern is much more striking than that expressed by cobalt. Cobalt is evidently more mobile than arsenic under the conditions of weathering in this locality, and the relatively insoluble arsenic becomes an indicator element of greater value in the precise location of ore than is cobalt—the metal of the ore sought.

In most places displacement of a soil anomaly through creep or slide can be understood and readily interpreted in terms of local geological evidence. The displacement of a geochemical anomaly in residual

soil so thoroughly leached that a substantial volume of material had been removed was established by Survey work at Friends Station, Tenn. Here a deposit that dipped at a moderate angle would project to the surface a substantial distance from the actual outcrop of the residual ore material in the weathered soil, because approximately two-thirds of the original volume of the limestone had been dissolved to form the residual soil. In such localities the importance of establishing the third dimension of the geochemical anomaly in both soil and bedrock is very apparent.

In arid regions where residual soils are lacking, metals otherwise mobile may be carried a substantial distance as detritus. In the San Manuel district of Arizona the alluvium from washes that do not receive detritus from the weathered orebody contain about 40 ppm of copper, whereas the alluvium in the dry stream bed that crosses the orebody carries 600 ppm a half mile below the ore outcrop. Detrital dispersion trains of materials that weather readily under mild humid conditions may also be formed through the work of glaciers.

In addition to the mechanical dispersion trains found in glacial drift which seem reasonable enough, there are many instances of superimposed diffusion halos in barren detritus, either glacial or alluvial, that has been swept over an orebody by the agents of erosion. This somewhat surprising situation probably reflects diffusion of the ore metals through damp silty and clayey overburden in contact with the oxidizing ore of the bedrock. Such diffusion may be related to the electric field that attends the oxidation of the sulphide orebody and may be the chemical partner of a self-potential geophysical anomaly.

In areas where thin soil or colluvium lies under a heavy vegetation ground cover, as in some parts of the Arctic tundra, rapid sampling with a sharpened pipe a few feet long has been tried with success by Survey geologists. In the first use of this technique three antimony deposits were found in southeast Alaska last year where there was no outcrop visible.

It is well known that certain plants may be very useful in showing the presence of geochemical anomalies not readily apparent at the surface. Ideally the root systems of trees and other vegetation can be powerful sampling mechanisms that bring certain mobile elements up from the subsoil or bedrock through distances as great as 50 to 75 ft. Plants that take up relatively large amounts of certain elements are called *accumulator plants*, whereas those that show a strong preference for areas where certain elements are abundant but do not take up large amounts of the elements in question are known as *indicator plants*. Both are of use in prospecting.

In analytical work on vegetation the heavy metal content of the geobotanical samples must be compared on the basis of identical species and not of one species with another, and preliminary work should establish which plants are to be used. In western United States the USGS has found that willow, aspen, spruce, sage, and selenium indicator plants are especially well adapted for geochemical exploration. The geobotanical work by the USGS has resulted in finding certain uranium orebodies. It is reported in the literature that plant analysis led to the discovery of tin and tungsten deposits in Cornwall, vanadium-bearing shale in Sweden, a tungsten deposit in Sweden, and a number of mineralized areas in southern Canada and elsewhere. Further work on this interesting technique is being carried on by many scientists both in the USGS and outside.

Geochemical methods should be simple, rapid, and inexpensive. Low cost personnel should be able to operate them with relatively little training. A fair degree of precision—reproducibility of results—rather than a highly quantitative accuracy is the end sought in applied geochemical prospecting. It is always desirable to make preliminary orientation surveys so that the geochemical problems and the sampling problems can be evaluated before a full-scale geochemical program is begun. Geochemical surveys may fail needlessly even when the analytical work is satisfactory if the wrong type of chemical anomaly

(Continued on page 966)

Selected Bibliography

L. H. Ahrens: The Lognormal Distribution of the Elements. *Geochim. et Cosmochim. Acta*, 1954, v. 3, pp. 49-73.

Hy Almond and H. T. Morris: Geochemical Techniques as Applied in Recent Investigations in the Tintic District, Utah. *Economic Geology*, 1951, v. 46, pp. 608-625.

F. C. Canney, H. E. Hawkes, G. M. Richmond, and J. S. Vhay: A Preliminary Report of a Geochemical Investigation of the Blackbird District: *USGS*, Open File Report, Dec. 21, 1953.

Helen L. Cannon: The Effect of Uranium-Vanadium Deposits on the Vegetation of the Colorado Plateau. *American Journal of Science*, 1952, v. 250, pp. 735-770.

Helen L. Cannon: Geobotanical Reconnaissance Near Grants, N. Mex. *USGS, Circ. 264*, 1953, 8 pp.

Paul Dorn: Pflanzen als Anzeichen für Erzlagerstätten. Der Biologe (Munich), 1937, v. 6, pp. 11-13.

D. L. Graf and P. F. Kerr: Trace Elements Studies, Santa Rita, N. Mex. *GSA Bull.*, 1950, v. 61, pp. 1023-1052.

Frank Grimaldi, Irving May, M. H. Fletcher, and Jane Titcomb: Collected Methods for Analyses of Uranium and Thorium. *USGS Bull. 1006*, 1954, pp. 1-184.

Earland Grip: Tracing of Glacial Boulders as an Aid for Ore Prospecting in Sweden. *Economic Geology*, 1953, v. 48, pp. 715-725.

John W. Harbaugh: Geochemical Prospecting Abstracts Through June 1952. *USGS Bull. 1000A*, 1952, pp. 1-50.

H. E. Hawkes and H. W. Lakin: Vestigial Zinc in Surface Residuum Associated with Primary Zinc Ore in East Tennessee. *Economic Geology*, 1949, v 44, pp. 286-295

H. E. Hawkes: Geochemical Investigations in the Nyamba Lead-Zinc District, Nigeria. *USGS 1000B* (In press).

H. E. Hawkes: Principles of Geochemical Prospecting. *USGS 1000* (In press).

Alvar Högbom: Ommoranblock ochblocktransport urbraktiahgeologisk synpunkte. *Geol. Fören. Stockholm*, Förh., 1931, v. 53, pt. 2, no. 385.

L. C. Huff: A Sensitive Field Test for Heavy Metals in Water. *Economic Geology*, 1948, v. 43, pp. 675-684.

L. C. Huff: Abnormal Copper, Lead, and Zinc Content of Soil Near Metalliferous Veins. *Economic Geology*, 1952, v. 47, pp. 517-542.

E. C. Hunt, A. A. North, and R. A. Wells: The Application of Paper Chromatographic Methods of Analysis to Geochemical Prospecting. Unclassified Report of the Chemical Research Laboratory at Teddington, England (No. C.R.L./A.E. 114).

V. C. Kennedy: Mineralization Surrounding Ore in the Southwestern Wisconsin Lead-Zinc District. Unpublished Ph.D. thesis, Pennsylvania State College.

H. W. Lakin, Hy Almond, and F. N. Ward: Compilation of Field Methods Used in Geochemical Prospecting by the U. S. Geological Survey. *USGS Circ. 161*, 34 pp.

Ernest Lidgey: Some Indications of Ore Deposits. *Australasian Institute of Mining Engineers Proceedings*, v. 4, pp. 110-122.

T. S. Lovering, L. C. Huff, and Hy Almond: Dispersion of Copper from the San Manuel Copper Deposit, Pinal County, Ariz.: *Economic Geology*, v. 45, pp. 493-514.

H. T. Morris and T. S. Lovering: Supergene and Hydrothermal Dispersion of Heavy Metals in Wall Rocks and Orebodies, Tintic District, Utah, Part 2. Primary Dispersion Pattern of Heavy Metals in Carbonate and Quartz Monzonite Wall Rocks. *Economic Geology*, v. 47, pp. 685-716.

T. B. Nolan: The Search for New Mining Districts. *Economic Geology*, v. 45, pp. 601-608.

E. A. Ratsbaum: Field Spectroanalytical Laboratory for Servicing Prospecting Parties (in Russian). *Razvedka Nedr.*, v. 10, no. 1, pp. 38-41. Translated by V. P. Sokoloff: *Selected Russian Papers on Geochemical Prospecting for Ores, USGS*, pp. 1-6.

W. O. Robinson, H. W. Lakin, and L. E. Reichen: The Zinc Content of Plants of the Friedensville Zinc Slime Ponds in Relation to Biogeochemical Prospecting. *Economic Geology*, v. 42, no. 6, pp. 572-582.

A. A. Saukov: Geochemistry of Mercury (in Russian). Akad. Nauk SSSR, Inst. of Geol., *Nauk Trudy*, 1946, v. 78, Mineral-Geokhim, ser. no. 17, 139 pp.

Martti Saimi: Trace Elements in Peat: *Geol. Tutkimuslartos, Geotek. julkaisuja*, 1950, no. 51, 20 pp.

V. P. Sokoloff and H. E. Hawkes (translators): *Selected Russian Papers on Geochemical Prospecting for Ores*, 103 pp. Released for free public distribution on April 14, 1950.

H. V. Warren, R. E. Delavault, and R. I. Irish: Improved Dithizone Field Test for Heavy Metals in Water. *GSA Bull.*, 1951, v. 62, pp. 609-618.

H. V. Warren, R. E. Delavault, and R. I. Irish: Acetonic Dithizone in Geochemistry. *Economic Geology*, 1953, v. 48, pp. 306-311.

W. H. White and T. N. Allen: Copper Soil Anomalies in the Boundary District, British Columbia. *AIME Trans.*, 1954, v. 199, pp. 49-52.

is sought, or if the samples were taken in the wrong places, in the wrong materials, or with the wrong spacing. Preliminary work should establish the elements sought, the material best suited for sampling, the most effective analytical procedure, the best geometric pattern for sampling, and the maximum permissible spacing of the samples necessary to reveal anomalies. The techniques selected depend on the kind, size, and the homogeneity of the anomaly and on its general shape, e.g., a dispersion train, a dispersion fan, or a dispersion halo.

Since most surficial geochemical anomalies result from movement of soil, water, or rock, the factors that should determine the geometry of the sample pattern are the direction of movement, the topography, and the size and shape of the source of the material. Before working with primary geochemical anomalies it is essential that a good geologic study of the deposit be made. The sample spacing for any anomaly should be such as to assure that at least one or more samples will fall within the zone of an anomaly. In known target areas geochemical samples may be spaced as closely as 10 ft apart or as widely as several hundred feet apart, depending upon local conditions. District size targets are usually sought by investigation of streams and their sediments, and samples may be spaced more than a mile apart if the anomalous metal content can be detected by water samples several miles from the source. Obviously those geologic conditions permitting a wide spacing of samples are especially suitable for geochemical prospecting in virgin territory.

Ore deposits make up a very small fraction of the earth, and one of the principal objectives of the prospector is to pick up the most favorable area for intensive study as quickly and cheaply as possible. On entering a new region the exploration geologist will use cheap, rapid reconnaissance methods so far as is feasible and after the elimination of unfavorable localities will make an increasingly intensive study of the favorable areas to reduce the size of the target that must be proved by physical investigation. Under favorable circumstances geochemical methods can help the exploration geologist enormously, and no modern mining geologist can afford to be ignorant of this powerful new tool.

Magnetic Storm Monitor

by W. E. Wickerham

THE Magnetic Storm Monitor is an instrument that continuously records variations in the earth's total magnetic field at a fixed location. It is intended for use in conjunction with airborne magnetometer surveys.

There are stormy periods when changes in the earth's magnetic field are so violent that data obtained with airborne equipment would be of little value. The Monitor provides this information so that flights may be cancelled or terminated, thus eliminating useless flying. Moreover, when some unpredictable change in the earth's field occurs during an airborne survey, the Monitor record, showing a similar event, may serve to salvage the data.

The utility of a base instrument is determined largely by its physical dimensions, power requirements, stability, and reliability. This instrument is small enough to be transported in any powered vehicle. It will operate from either a 110 v, 60 cycle power line or from an inverter powered by an automobile battery. The development of an electronic feedback circuit that measures the magnetic field strength and a fabricated buckout magnet having essentially zero temperature has contributed to instrument stability and reliability. A tripod supporting the magnetometer head, a chassis housing all electronic components, and an Esterline Angus Recorder comprise the equipment, shown in Fig. 1. The vibrator-type inverter shown is used when a 110 v, 60 cycle power line is inaccessible. Approximately 60 w are required to operate the instrument and the circuit is insensitive to reasonable power line voltage changes or transients.

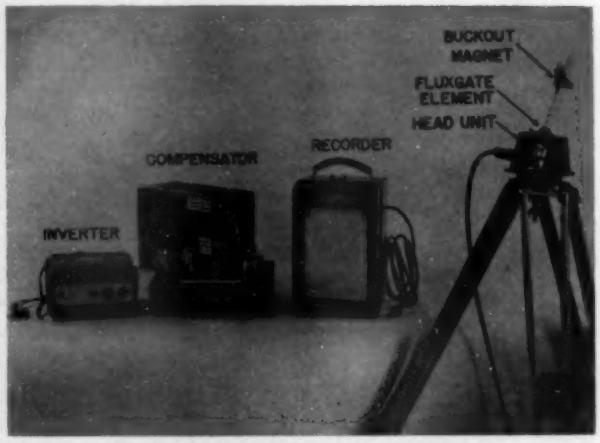


Fig. 1—Photograph of the entire equipment.

The head unit contains a fluxgate-type magnetometer element and a special magnet mounted on a ceramic structure. Since this magnet is used to buck out most of the earth's field, adjustments are provided for properly positioning the magnet with respect to the element. This assembly is mounted in such a way that the element can be oriented into the total field.

Fluxgate Element: The heart of the Storm Monitor is a fluxgate-type magnetometer element. The ability of this unit to detect changes in magnetic fields has been covered at length in the literature.[1, 2] For this discussion it will suffice to say that the Gulf

W. E. WICKERHAM is with Gulf Research and Development Co., Pittsburgh.

Discussion on this paper, TP 4044L, may be sent (2 copies) to AIME before Dec. 31, 1955. Manuscript, Feb. 9, 1955. Chicago Meeting, February 1955.

element comprises two coils having ferromagnetic cores which are driven cyclically through saturation. A secondary or compensating coil encompasses both primaries. The primaries, connected in series opposition, are arranged so that one core saturates slightly ahead of the other core and the resultant output is in the form of sharp pulses as shown in Fig. 2 (a). The positive and negative pulses are equal in amplitude when external magnetic fields are zero.

The relative amplitude of the pulses is related to the state of magnetization of each core during the positive and negative half cycles of excitation voltage. If both cores saturate at exactly the same time, complete cancellation of the voltages will produce zero output. Purposely unbalancing one coil causes a given core to saturate first during either half cycle of excitation voltage. The state of magnetization of the cores is identical in either case; consequently, positive and negative pulses are equal in amplitude.

In the presence of some ambient field, the time at which the individual cores saturate is altered. This produces a change in output as shown in Fig. 2 (b). A reversal in the ambient field causes a reversal in output as in Fig. 2 (c).

A permanent magnet moved near the element will influence the output as in Fig. 2 (b) or 2 (c), or if the earth's field is causing pulse inequality, a permanent magnet may be used to restore pulse equality.

The element ouput can also be controlled by passing direct current through the secondary coil; in this case the created field will aid or oppose the earth's field. A given polarity of current through the coil produces output as in Fig. 2 (b) and with the current reversed, the output is like Fig. 2 (c).

Electronic Compensator: The foregoing suggests that if the element is exposed to an ambient magnetic field and the pulses become unequal, dc current of the proper amount can be passed through the secondary coil to restore pulse equality. A measurement of the current required to do this constitutes a measurement of the ambient field, and if the coil is properly calibrated, the current can be translated into terms of magnetic field strength.

The electronic compensator supplies dc current to the compensating coil in a direction which tends to nullify the earth's field at the element. The entire circuit, including the magnetometer element, is a feedback loop that is conducive to excellent stability.

The signal from the magnetometer element is used to control the amount of current feeding through the compensating coil. The element senses the need for a change in current when the earth's field is not nullified and the compensator complies by changing the current in a direction to re-establish the null.

With reference to the block diagram, Fig. 3, a stabilized 400 cycle oscillator is used to excite the fluxgate element. The output of the element is in the form of alternate positive and negative pulses, as previously described.

It is essential that the pulses to be amplified and shaped possess the same polarity so that they may be passed through the same single-channel amplifier, since the single channel insures that both pulses will be treated alike in the process. A balanced thermionic diode is used to convert the alternating polarity pulses from the element into unidirectional pulses suitable for input to the single-channel amplifier and shaper. A reversal switch is provided to check diode balance and an adjustment is provided to correct for minor differences in balance.

The amplifier and shaper prepares the signal for charging a differential filter. Any inequality existing in the pulse input will be exhibited as unequal sawteeth at the output of the amplifier.

The sawteeth are fed into a gated vacuum tube circuit. Four-hundred cycle voltage controls one gate in such a way as to pass a given sawtooth and reject the following one. Likewise, the other gate is phased to pass and reject alternate sawteeth in the reverse order from gate No. 1. The output of each gate will be noted on the diagram, Fig. 3.

Two filter networks are charged from the output of the two gates and for equal sawteeth, the combined filter output is zero. For unequal sawteeth, the polarity of the dc voltage at the filter output is established by the relative sizes of input sawteeth.

The differential filter output controls a tube which is feeding current through the compensating coil. When the pulses become unequal, the filter output is phased in a manner to restore pulse equality and the change in current required to do this is measured by a recording milli-ammeter.

It is essential that the sensitivity of the recorder be high enough to resolve a field change of 1 or 2 gamma. This is accomplished by bucking out most of the earth's field with a special magnet and recording

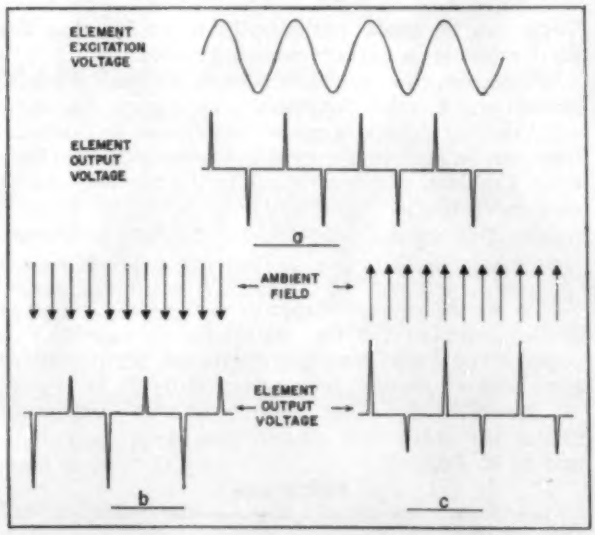


Fig. 2—Fluxgate element pulse wave forms.

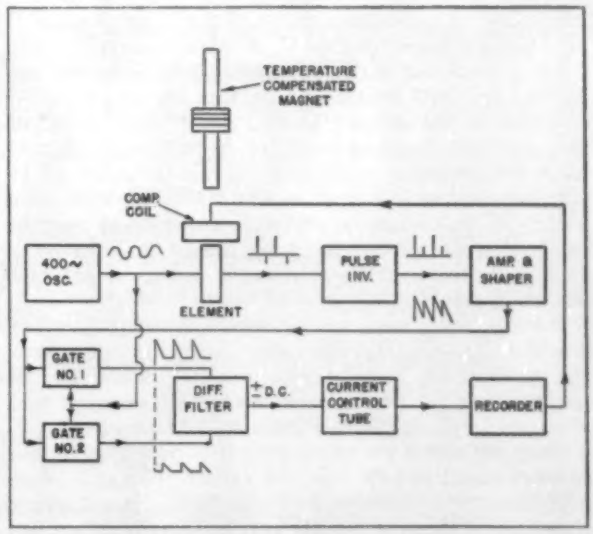


Fig. 3—Block diagram of equipment used.

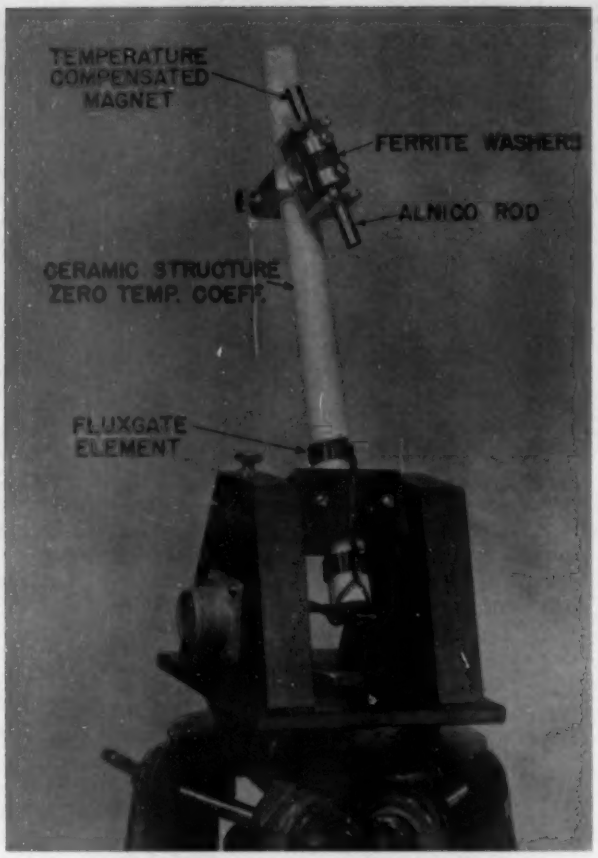


Fig. 4—Photograph of magnet, mounting, and tripod head.

the residue. The sensitivity used is 250 gamma for full-scale deflection of the one milli-ampere recorder. The recorder can be shunted to lower the sensitivity. This causes overdamping, but slow changes can still be observed.

Since the buckout magnet is one of the unique features of this instrument, some details of its construction follow.

Temperature-Compensated Magnet: Permanent magnets exhibit negative temperature coefficients, which means that their magnetic moment decreases as the temperature is raised. Several Alnico bar magnets have been measured and found to have a coefficient of approximately -16×10^{-5} per degree C or -0.016 pct per degree C. If such a magnet were used to buck out a 50,000 gamma field (an average figure) the drift would be 8 gamma per degree C.

Some of the widely publicized ferrite materials meeting the requirements for permanent magnets have temperature coefficients on the order of -0.16 pct per degree C. This is ten times greater than alnico. A theoretically perfect compensated magnet can be made by opposing an alnico magnet by a ferrite magnet having a moment about 10 pct that of the alnico.

Ferrite magnets can be made in the form of washers. In practice, this offers a convenient means for assembling a composite magnet, since ferrite washers can be slid onto an alnico bar magnet and clamped in place. Such a magnet is shown in Fig. 4. To compensate a given magnet it is practical to use several small ferrite washers rather than one large one, since this provides some flexibility in adjusting moments. A ferrite washer can be ground, if necessary, to accomplish the final adjustment.

Mounting for Magnet and Element: Changes in distance between the buckout magnet and the element can cause serious drifts. Magnetic field strengths at the element may be considered to be inversely proportional to the cube of the distance between the magnet and element in this application. Algebraically expressed,

$$F \alpha \frac{1}{D^3} = \frac{K}{D^3}$$

where f = magnetic field strength, D = effective distance between the magnet and element, and K = a constant whose value is fixed by the units used for F and D.

A small change in distance ΔD will cause a field change:

$$\Delta F = \frac{-3F}{D} \Delta D.$$

For example, if the field is 50,000 gamma for a spacing of 4 in., a change of 0.001 in. in D gives

$$F = \frac{-3 \times 50{,}000}{4} \times 0.001 = -37.5 \text{ gamma.}$$

It will be clear that if serious drifts are to be avoided the magnet must stay fixed with respect to the element. This is accomplished by using a zero temperature coefficient ceramic material to support the element and the magnet.

Operational Procedure: The tripod and head assembly should be set up in a shaded location. Initial adjustments can be made by one man with the amplifier and recorder approximately 15 ft away from the head. It is recommended that the units be separated approximately 100 ft in the final setup to avoid magnetic disturbances by cars driving up to the base station. Direct sunshine or gusts of wind can cause local dimensional changes in the mounting or even in the tripod legs, the latter resulting in misorientation with respect to the earth's field. Either effect will in turn show up as drift. Slow thermal changes can be tolerated. A tent or collapsible wooden hut has been found to be advantageous for sheltering the tripod.

With the instrument running, positioning the buckout magnet will bring the recorder on scale. The element can be oriented manually into the total field by manipulation of the head adjustments until maximum field strength is indicated on the recorder. Tests can be made periodically to insure that the equipment is in proper working order.

Obviously, time synchronization between the base station and aircraft recorders is necessary. For ordinary service a clock or pocket watch can be used and time can be indicated manually on the records. However, a marker pen is provided in the recorder which can be actuated electrically to establish fiducial marks if automatic time-fiducial marking is desired.

Acknowledgment

The writer expresses thanks to the Gulf Research & Development Co. for permission to publish this paper. The basic idea for making a temperature-compensated magnet was proposed by R. D. Wyckoff. Some of the other features of this instrument utilize the work and cooperation of O. K. Doolen and N. C. Pflaum.

References

[1] Gary Muffly: The Airborne Magnetometer. *Geophysics*, July 1946, v. 11, no. 3.
[2] R. D. Wyckoff: The Gulf Airborne Magnetometer. *Geophysics*, April 1948, v. 13, no. 2.

aime news

Industrial Minerals Div. Fall Meeting
Charlotte, N.C., October 27, 28, and 29th

This fall the Industrial Minerals Div. turns to the Southeast for its meeting site. Headquarters for the two days of technical sessions will be the Hotel Charlotte, Charlotte, N. C.

The technical session Thursday afternoon will be followed by a cocktail hour and dinner. An after-dinner speaker will present an informative talk on legal pitfalls for engineers.

On Friday the sessions will last all day, again being followed by a period of social activities.

Field Trips

On Saturday the group heads for the Kings Mountain area where the following field trips have been arranged: the kyanite operations of the Commercialores Inc.; mining and milling of mica at Kings Mountain Mica Co.; mining and crushing of spodumene ore at Foote Mineral Co.; and if time permits, a visit to operations of the Superior Stone Co.

Charlotte, N. C., site of the Industrial Minerals Fall Meeting.

TECHNICAL SESSIONS — SOCIAL EVENTS — FIELD TRIPS

PROGRAM

Thursday, Oct. 27

9:00 am: Registration

10:00 am: Executive Committee

12:00 m: Luncheon

1:30 pm: Technical Session

Appalachian Geology and Mineral Deposits. By Byron Cooper, Geologist, Blacksburg, Va.

Ground Water in the Igneous and Metamorphic Rocks of the Southern Appalachians. By H. E. LeGrand, USGS

Mineral Operations in the Southeast. By T. L. Kesler

Titanium—From Ore to Metal. Movie—National Lead Co.

Social Hour

Dinner—Speaker

Friday, Oct. 28

9:30 am: Technical Sessions

Symposium—Quality Control for Industrial Minerals

Mica. By Ralph Adair

Barite. By L. G. Wilson

Kyanite. By C. Beers, Commercialores Inc.

Titanium Minerals. By R. M. Lewis, Humphreys Gold Corp.

2:00 pm: Technical Session

Kaolin—Mining and Milling. By J. Walton, Minerals & Chemicals Corp.

Blasting Techniques. By W. I. Duvall, USBM

Pegmatite Mining for Spodumene. By E. R. Goter and Ralph C. Flow, Foote Mineral Co.

Social Hour

Dinner Dance—Informal

Saturday, Oct. 29—Field Trips

Around the Sections

• The **Pikes Peak Subsection** of the Colorado Section held a meeting at Cripple Creek, Colo., Aug. 27, 1955. The program included a technical session at Carlton mill of the Golden Cycle Corp. at Victor, Colo. The speaker was James H. Keener of the Stratton Cripple Creek Mining & Developing Co., who spoke on a recent uranium find on Stratton lands. A trip through the mill was conducted after the meeting. A cocktail hour and dinner was held at the Imperial Hotel and the evening's entertainment was topped with a melodrama by the Imperial players.

• The **Colorado Plateau Section** and the **Minerals Beneficiation Subsection** held a joint meeting at the Hotel Denver, Glenwood Springs, Colo., Sept. 17, 1955. The afternoon business meeting and technical session was followed by a cocktail party, dinner, and dance.

• The **Minnesota Section** held a meeting on Wednesday, Aug. 24, 1955, at Minneapolis. Felix E. Wormser, Assistant Secretary of the Interior, was the special guest.

• The **Southern Nevada Subsection** held its last meeting before the summer at the Swanky Club in Henderson, Nev. Mr. Lazar, professor of psychology at Nevada Southern University, and George Bowman, president of the Las Vegas Rotary Club, were guest speakers. Mr. Lazar spoke about future plans and the curriculum of the new school and Mr. Bowman spoke on the financing of the new university. Twenty-six members and six guests were present.

• The **Minnesota Beneficiation Subsection** has announced the slate of officers for its fifth year. John Boentje, the new subsection chairman, is general manager of the Pacific Isle Mining Co., Hibbing. The vice chairman of the subsection, Richard W. Livingston, is an ore dressing engineer for the Jones & Laughlin Steel Corp. at Calumet, Minn. Chelsea R. Phillips, newly elected secretary-treasurer of the MBD subsection, is sales engineer representative in the Iron Range area for Hewitt-Robins Inc.

• Jack Myers, for many years at Tennessee Copper Co. and now with Denver Eqpt. Co., was the speaker of the evening at the Aug. 27 meeting of the **Adirondack Section.** The site of the meeting was the Tupper Lake Country Club, Tupper Lake, N. Y.

• The second Alumni Reunion of the Minnesota School of Mines and Metallurgy will be held Friday, Oct. 21, 1955. A technical session is scheduled for Friday at the school, and in the evening there will be a cocktail hour followed by a banquet and dance at the Nicollet Hotel. Saturday will be open house, followed by the Michigan-Minnesota football game. Make reservations for tickets and hotels early by contacting R. L. Dowdell, 306 Appleby Hall, Minneapolis 14, Minn.

Student chapter members at the Wisconsin Institute of Technology are shown erecting a sign at the site of the big "M" which is the official symbol of the miners at the institute, formerly Wisconsin Mining School. The students designed and built the giant letter, quarrying and placing 400 tons of limestone.

• **A full color and sound, 23 min. 16-mm motion picture titled** *Flaw Location with Dye Penetrants* **has been completed by Turco Products Inc. and is available for free showing to industrial concerns, technical groups, and other interested organizations. The film, which is intended primarily for training purposes, visually demonstrates every aspect of dye penetrant inspections.**

• *Mining for Nickel,* **new film on the mining operations of The International Nickel Co., was two years in the making. The 45-min sound-color film outlines briefly the history of nickel mining in the Sudbury area of Canada and covers in detail the original development of a mine and the six methods of extracting ore employed by Inco. The picture was produced by Film Graphics Inc. in Eastman color. Prints of** *Mining for Nickel* **are now available for educational, industrial, and civic groups through the Douglas D. Rothacker, Jr., organization, 729 Seventh Ave. or The International Nickel Company Inc., 67 Wall Street, New York City.**

• **The Scientific Apparatus Makers Assn. has a directory of 14 motion pictures on subjects ranging from optical instruments to basic electronics. Film information is outlined for each picture according to title, film size, running time, description of picture, and source. Single copies of the SAMA motion picture film directory may be obtained free from: Public Information Committee, Scientific Apparatus Makers Assn., 20 North Wacker Drive, Chicago 6, Ill.**

Drilling Symposium

The annual drilling symposium sponsored by the University of Minnesota will be held on the Minneapolis campus October 13, 14, and 15th. Key topic this year is use of tungsten carbide in rotary drilling for exploration purposes.

Thursday: Morning session on "The Metallurgy of Tungsten Carbide" and afternoon session devoted to "The Mounting and Arrangement of Tungsten Carbide in Bits."

Friday: A morning session will cover "Experience of Rotary Drillers with Tungsten Carbide in Bits." The afternoon topic is "Combined Use of Rotary and Percussive Methods with Tungsten Carbide Bits."

Saturday: A morning meeting will be devoted to general discussion of rotary drilling topics.

Research Conference

The University of Missouri School of Mines and Metallurgy and the U. S. Bureau of Mines "Conference on Mining Research" is open to all those interested in the mining industry.

The conference will be held on the Mines campus at Rolla, Mo., October 17 and 18. Program subjects include: research by the USBM; research on drilling and blasting by Missouri School of Mines; stripping methods for clay deposits; drilling and sampling bauxite with auger drills; mining research in the lead belt; use of the Linde jet drill in quarrying; and an open forum on mining problems.

For housing, contact George B. Clark, chairman, Dept. of Mining Engineering, School of Mines, Rolla, Mo.

1956 Annual Meeting Program Takes Shape — Progress Reports from Divisional Program Chairmen

Geology Subdivision Urges Early Submission of Papers For Annual Meeting

At the 1956 Annual Meeting to be held in New York at the Statler and New Yorker hotels February 20 to 23, the Geology Subdivision will meet jointly with the Society of Economic Geologists. Tentative plans include symposia, with invited speakers, on "Natural Concentrations of Rare and Alloy Metals" and "Late Stages of Rock Crystallization in Relation to Ore Deposition" (these suggested by the Geology Subdivision) and on "The Chemistry of Ore Forming Fluids" (suggested by the SEG).

In addition, the SEG is interested in papers on the economic geology of coal, ore deposits, and industrial minerals, as well as applications of geology to problems of engineering and ground water. The Geology Subdivision plans to reserve half its allotted time to miscellaneous papers and welcomes any carefully prepared paper on a topic of interest.

Those wishing to introduce papers for presentation should submit title of paper, name and address of author, and acceptable abstract to any one of the following:

Edward Wisser, Chairman, Program Committee, Geology Subdivision, AIME, Div. of Mineral Technology, University of California, Berkeley 4, Calif.

Charles H. Behre, Jr., Chairman, Program Committee, SEG, Dept. of Geology, Columbia University, New York 27, N. Y.

Olaf N. Rove, Secretary, Society of Economic Geologists, 30 E. 42nd St., New York 17, N. Y.

Closing date for submission of such papers is Dec. 20, 1955, but it is urged that papers be sent in as much before that date as possible.

Back in New York again for the 1956 Annual Meeting of the AIME, the Mining Branch is planning a program that should bring a large group of members even from as far away as the Pacific Coast. With Super Constellations flying from Los Angeles to New York nonstop in 7 hr and 50 min at an air-coach fare of $88.00, including tax, even the budget-minded should be able to make the meeting from most any part of the country. (That fare, it should be noted, applies only for passengers making the round trip, Monday through Thursday, with a 30-day return limit.)

Again, the Statler will be headquarters, with the banquet at the Waldorf-Astoria. Saturday, February 18, the clans will begin gathering, with an all-day meeting of the Council of Section Delegates. Sunday there are several committee meetings and a Board of Directors meeting, and the educators get under way with an afternoon and evening session. Monday the eight-ring circus really gets under way. Social events include the All-Institute Welcoming Luncheon on Monday, a free cocktail party, a dinner-smoker that night, an informal dance Tuesday night, and the banquet and dance Wednesday. Branch and Divisional dinners and luncheons fill all the spare time from Tuesday till Thursday afternoon, February 23. There will be no time out for Washington's Birthday—that will be celebrated at the Banquet.

Mining Div.

Program committees have been busy. The entire North and South American mining field has been combed for reports on the newest in mining practice. Roger Pierce has seven sessions lined up. One will be a Latin American session, another entirely devoted to Canada. One session will consist of three or four papers on important uranium mining operations. A fourth session will include both underground and open pit mining papers, and a fifth will include such topics as steel sets for underground mining support, Howe Sound's cobalt operations in Idaho, and modern hydraulic phosphate mining practice in Florida. The Jackling Lecture will be followed by a symposium on the Osceola pumping project of Calumet & Hecla, surely a subject about which a mining man needs to know as much as possible. The seventh session includes an interesting paper on rock bolting by the Banner Mining Co. in Arizona. Other subjects will be mentioned in future issues of MINING ENGINEERING. The seven program chairmen who are developing all this interesting fare are Elton Youngberg of Grand Junction; C. C. Huston of Toronto; Russell Merz of New York and Peru; Allan Bowman of Tucson; John Hall of Tahawus, N. Y.; Darwin Pope of New York; A. S. Kromer and staff of Calumet, Mich.; and John Bley of Nye, Mont.; with Elmer Jones of Bonne Terre in charge of the Jackling Lecture.

Geology & Geophysics

Geology and geophysics will also be represented by several sessions. As usual, the Society of Economic Geologists is contributing to the geological program. Details will be given in a succeeding issue, but two symposia are planned. One will be on final rock crystallization in relation to ore deposition. Basis for this is recent field work on the Boulder Batholith, where a genetic connec-

(Continued on page 974)

Newmont Mining Corporation

announces the removal of its

New York offices to

300 Park Avenue, New York 22, N. Y.

Effective
October 15, 1955

Telephone
PLaza 1-3060

ATLAS COPCO EQUIPMENT POURS INTO TURKEY TO DEVELOP CHROME ORE MINING INDUSTRY . . . . .

Turkey during the last few years has become the world's main producer of metallurgical grade chrome ore. Though it has been mined and exported from there for over 90 years, it wasn't until recently that it was produced in any quantity. The reason for neglect was Turkey's high transportation costs. Consequently, the only deposits developed were those near the coast or indeed any place where transport was easy enough to allow a decent profit.

The location of Turkey's chrome ore mining areas. The majority of the mines employ Atlas Copco compressors and Atlas Copco light rock drills fitted with Sandvik Coromant tungsten - carbide - tipped drill steels.

A repair shop on wheels! This fully self-contained vehicle belonging to Atlas Copco Ticaret ve Sanayi T.A.S., tours chrome ore mining areas servicing Atlas Copco equipment and Sandvik Coromant drill steels.

CHROME EXPORTS RISE RAPIDLY

In 1950 came the Korean War and everything changed. The price of chrome in world markets soared. Mining the ore in out-of-the-way regions at last became a paying proposition and small mines were opened up in large numbers. These export figures supplied by the Turkish Chrome Committee indicate the increased development of metallurgical grade chrome ore during the past seven years:

	METRIC TONS
1948	100.000
1949	146.627
1950	200.000
1951	330.000
1952	462.532
1953	492.777
1954 (Jan.-Aug.)	239,031

ROCK DRILLS BY THE HUNDREDS!

In early 1951, Atlas Copco equipment poured into Turkey for the modernisation of old

mines and the working of new ones. The Atlas Copco company in Turkey, Atlas Copco Ticaret ve Sanayi T.A.S., supplied this equipment. Latest figures of Atlas Copco equipment now being used in the industry are given at over one hundred stationary and portable compressors and about three hundred light rock drills. These are fitted with Sandvik Coromant tungsten-carbide-tipped drill steels—the world's most widely used integral drill steels.

An Atlas Copco rock drill fitted with a Sandvik Coromant drill steel at work. The drill is one of three hundred supplied by Atlas Copco to the Turkish chrome ore mining industry since 1951.

IMMEDIATE BOOST TO PRODUCTION

The effect that Atlas Copco equipment has had on production comes out in the above tables of Turkish chrome ore exports which constitute practically the whole of the industry's production. 1951—the year Atlas Copco drills and Sandvik Coromant drill steels were introduced—saw the biggest leap in the amount of chrome ore mined. 130,000 metric tons over the 1950 total! Look at that last figure again and you'll realise the big difference Atlas Copco mining equipment can make.

Atlas Copco Compressed Air Equipment is manufactured or sold and serviced in 48 countries throughout the world by *The Atlas Copco Group*, which embraces companies trading under various names such as Atlas, Atlas Diesel, Atlas Polar, Atlas Copco, Copco, Delfos and Sampa.

An Atlas Copco P-8/600 centrifugal sump pump being placed in position. Many of these pumps are among the wide range of Atlas Copco equipment sent to Turkey.

* *Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment*

THE ATLAS COPCO GROUP OF COMPANIES

MAIL THIS COUPON to the most convenient of the addresses given here:

U.S.A., Copco Pacific, Ltd., 930 Brittan Avenue, San Carlos, California; Copco Eastern, Ltd., P.O. Box 2568, Paterson 2, N.J.; CANADA, Canadian Copco, Ltd., Montreal, A.M.F., Quebec; MEXICO, Atlas Copco Mexicana, S.A., Apartado Postal 56, Torreon, Coahuila; PERU, Compania Atlas del Perú, S.A., Apartado 2982, Lima.

UNITED KINGDOM, The Atlas Diesel Co., Ltd., Wembley, Middx.; FRANCE, Atlas Polar S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, N.V. Holland-Atlas, P.O. Box 6056, Rotterdam; ITALY, S.A.M.P.A., Viale Marche 15, Milan.

AUSTRALIA, Australian Atlas Company Pty., Limited, P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos Pty. Ltd., P.O. Box 504, Benoni, Transvaal.

Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write, in the first instance, to AB Atlas Diesel, Stockholm 1, Sweden.

Please forward details of ***Atlas Copco Rock Drills and Sandvik Coromant Drill Steels***

NAME.....

COMPANY.....

ADDRESS.....

.....4/5

* I am also interested in other Atlas Copco equipment (*please state which below*)

Annual Meeting Program Report

(Continued from page 971)

tion between end products of magnetic differentiation, such as aplite on the one hand and lead and copper deposits on the other, is indicated. The other symposium will be on the geological concentration of rare and alloy metals such as niobium, lithium, titanium, tantalum, and beryllium.

Industrial Minerals

Eight or nine technical sessions are being arranged by the Industrial Minerals Div., J. J. Norton, program chairman. One will be a panel discussion on the relation of cement to aggregate. Another session on chemical raw materials will include papers on materials for nuclear power and on the economics of the rutile industry, with a probable symposium on phosphate or salt. The Committee on Fillers, Fibers, and Pigments is arranging a symposium on air separation and a paper on clay. That increasingly important industrial mineral, water, will be discussed probably in two sessions, one on water development planning and one on reclaiming waste waters and related subjects. Five or six papers on synthetic minerals are in prospect, the subjects being mica and asbestos, diamonds, quartz, gems, water-solubles, and semiconductors. Silica-feldspar sands for the glass industry will also be discussed.

Coal Div.

Theodore R. Jolley, program chairman for the Coal Div., indicates the subjects for his Divisional sessions as follows: Monday morning, utilization; Monday afternoon, gasification and carbonization; Tuesday morning and afternoon, a symposium on how to build a coal preparation plant; Wednesday, anthracite mining in the morning and bituminous mining in the afternoon; Thursday morning, mining research, and in the afternoon, general topics.

The Tuesday symposium will open with a paper discussing the influence of market demands on coal preparation. The second paper will deal with the selection of types of cleaning units for a coal-preparation plant, followed by formal discussions on jigs, dense-medium processes, wet tables, dry tables, and fine-coal Rheolaveurs. Afternoon papers will concern the selection of dewatering and drying equipment, dewatering screens, centrifuging, thermal dryers, water clarification, and quality of circulating water.

The newly appointed Materials Handling Committee chairmanned by R. U. Jackson is planning a symposium by three speakers who will discuss handling from working face to portal, from portal to preparation plant and railroad cars or other form of transport, and from mine to consumer including consumer storage and preparation for utilization.

Except for the Fuels Conference in the fall, this is the only meeting of the Coal Div. members during the year so they should make the most of it.

The nine functional committees of the Minerals Beneficiation Div. all have from two to nine papers assured as this is written early in September, says Program Chairman, Norman Weiss. The Concentration Committee has papers on flotation of uranium, the White Pine concentrator, potash, pegmatite and uraninite flotation, xanthate absorption on pyrite, Humphreys spirals in iron ore concentration, amine flotation of halides, and a study of quartz flotation.

MBD Committees

Crushing and grinding subjects will include the predicting of size distribution in classifier products, correlation of rod mill capacities with operating variables, the Aerofall mill, energy transfer by impact, and the effect of heat treatment on taconites. Materials handling papers will include one on tailing disposal at Morenci and one on conveyor transfer point redesign using photography. In the field of operating control there will be papers on reagent control in flotation and instrumentation in Mesabi iron ore treatment. Two papers by the Pyrolysis and Agglomeration Committee will be a discussion of the FluoSolids installation at Sparrows Point, and a discussion of sintered expanded aggregates. In the field of solid-fluids separation there will be some information on the relative merits of cylindrical and conical cyclones and on natural and synthetic polyelectrolytes.

Extractive Metallurgy

The Solution and Precipitation Committee will meet jointly with the Extractive Metallurgy Div. Some of the assured papers are on Cananea copper leaching, roasting of carnotite, titanium metal production, and treatment of Cuyuna Range manganese ore. Four papers on mill design will cover, respectively, research and metallurgical data interpretation, foundation investigations at White Pine, primary crushing plants, and the economics of a planned mining and milling project.

"How to Start Up a New Mill" will be the subject of a symposium, beginning with prestart organization, through the actual start-up, to the initial operations. Such names as Hamilton, Lindroos, Martin, McNeill, Hendricks, Lowe, and Arpi indicate that here is a chance to learn from the experts.—E.H.R.

Meeting Headlines

Mineral Economics Div.

A special new feature of the Mineral Economics program will be a review of the broad economic factors that have influenced the economic health of the U. S. this past year, and a forecast of the trends affecting the mineral industry for the coming year. This will be handled by an expert in the field, Charles Broderick, economist of Lehman Bros. This discussion alone should provide an excellent background for the annual industry reviews as well as other papers on the program. It is hoped that this feature will be the first of a series on the Mineral Economics Div. programs to deal with the broader and more fundamental features of economics.

Future Trends

A new project and series of studies by the U. S. Bureau of Mines will be introduced as "Measurement of Technological Trends in the Mineral Industries." This paper should be of particular interest to both the engineers and mine equipment groups. Another subject to be discussed is "Measurement of Trends in the Mineral Industry."

A feature of broad interest to all the industry will be a discussion by qualified experts on "Economic Outlook for Domestic Industries in Strategic Minerals Now Functioning Under Government Assistance." An attempt will be made to outline what the Government has accomplished in its assistance programs to spur expansion of such minerals as uranium, tungsten, molybdenum, chromite, and mercury; to present the current status of these programs; and more important, to outline some of the problems to be faced by the industry in the near future.

Seaway Report

A great deal of interest has been expressed in the St. Lawrence Seaway project and its long-term effect on the mineral industry. The broad aspects of this project will be covered, with an estimate of the flow of mineral products to be expected. This project will certainly affect the flow of iron ore, petroleum products, coal, rock products, chromite, and abrasive materials, as well as result in considerable engineering work which will consume mineral products.

Other papers include such projects "U. S. Markets for Minerals from the Canadian Point of View"; "Economic Factors in Cold Weather Operations"; "Economic Aspects of Atomic Fuels"; "How to Determine Whether or Not a Company Starting Up in a Competitive Field Will Pay Its Way and Be Able to Attract Capital"; and "Rapid Depreciation Procedures Under Recent Changes in the Tax Law."

New Mexico Geological Society 6th Annual Field Conference

The New Mexico Geological Society, in conjunction with the Roswell Geological Society, will hold its Sixth Annual Field Conference in South-Central New Mexico on Nov. 11, 12, and 13, 1955. Truth or Consequences, N. M., will be headquarters for all three days and participants will register the afternoon and evening of Nov. 10 at the Recreation Center.

On the first day, the conference will examine the Paleozoic section of the San Andres Mountains under the leadership of Frank Kottlowski. These mountains lie within the restricted area of the White Sands Rocket Project.

On the second day, the conference, led by Richard A. Jahns and Clay T. Smith, will travel to the Cuchillo Mountains where the structure and stratigraphy of the Iron Mountain mining district will be examined.

The final day will be spent in the Caballo Mountains under the guidance of Vincent Kelley, Caswell Silver, and Hugh Bushnell. Here the complete section from pre-Cambrian to Tertiary is exposed.

Requests for reservations, accompanied by an advance fee of $10.00, should be sent to Frank W. Podpechan, Box 899, Roswell, N. M. Reservations will be accepted until Oct. 24, 1955. Final cancellation date for refund of advance payment is Nov. 7, 1955. Those canceling reservations after November 7 are entitled to a guidebook. Checks should be made payable to the Roswell Geological Society.

Michigan Tech Sponsors Institute

Grover C. Dillman, president of Michigan College of Mining and Technology, Houghton, Mich., has announced that an institute on Lake Superior Geology will be held at the college on May 11 and 12, 1956. The theme of the meeting will be "Geological Exploration." The Michigan Geological Survey and the Exploration Subsection of the AIME Upper Peninsula Section are cooperating with the college in presenting the institute.

Theoretical and practical developments in techniques of ore search on both sides of the international border will be featured at the meeting. Geochemical, geophysical, geobotanical, and photogeological approaches in mineral deposits research will be presented by specialists from the U. S. Geological Survey, the Geological Survey of Canada, the Ontario Dept. of Mines, and from industry. Field trips will follow the conference.

Convener of the institute is A. K. Snelgrove, head of the Dept. of Geological Engineering at Michigan Tech.

20th International Geological Congress Plans Progressing

The organizing committee for the 20th International Geological Congress recently issued its first circular (in Spanish with an abstract in English) which will be sent to all those interested who have not already received a copy. The technical sessions will be held in Mexico City, Sept. 4 to 11, 1956. About 30 field trips are being planned, some from August 14 to September 3, and some from September 12 to 25.

Fifteen subjects for technical papers are listed in the circular; these papers may be in English, French, German, Italian, Russian, or Spanish. Length is limited to 5000 words.

For reservations and further details address: Comité de Organización del XX Congreso Geológico Internacional, Balderas 36, Despacho 302-A, México 1, D. F., México.

Over Half Century Experience in

Exploration and Development
Diamond Core Drilling
Grouting
Rock Breaking
Mining – Quarrying
and Tunnel Driving

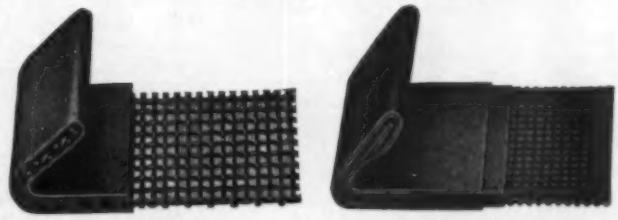
Full details on request

Boyles Bros. DRILLING COMPANY

1321 South Main St. • Dial HUnter 4-4401
Salt Lake City, Utah

Branch Offices:
Colville, Washington — Telephone 181
Leadville, Colorado — Telephone 526
Phoenix, Arizona — Telephone CRestwood 4-5331
Monticello, Utah — Telephone 2881 and 9184

Tyler Screen Sections for All Makes of Screening Machines!



Screen sections of Tyler Woven Wire are fabricated for all makes of vibrating screens in any mesh or metal. They are made up with hook-strip or bent-edge construction to suit the machine on which they are to be used.

Tyler rugged, accurately-applied hook-strips make possible stretching and maintaining the screens at drum-head tension, which is essential for successful screening and long screen life.

THE W. S. TYLER COMPANY
CLEVELAND 14, OHIO
Manufacturers of Woven Wire Screens and Screening Machinery

Canadian Plant—St. Catharines, Ontario, Canada

Max Krey and E. J. Schuh, geologi-

Rev. James B. Macelwane, dean, St.

Edward Wisser and **Manning W. Cox** have announced their association as the firm of Wisser & Cox, consulting geologists, at 55 New Montgomery St., San Francisco. Mr. Wisser is professor of mineral exploration, University of California, Berkeley. Mr. Cox was formerly exploration manager and chief geologist, Northwest mining district, American Smelting & Refining Co., Wallace, Idaho.

W. C. Spence has resigned from his position as concentrator foreman with Andes Copper Mining Co., Potrerillos, Chile, in order to attend Harvard Graduate School of Business Administration.

Ross W. Smith has completed requirements for a master's degree at MIT and is employed as an engineer by the Portland Cement Assn., Skokie, Ill.

Elmer R. Ramsey, former president, The Dorr Co., now Dorr-Oliver Inc., Stamford, Conn., has retired from the chairmanship of the Committee on Engineering Laws. He has been associated with the committee since its inception in 1953. Mr. Ramsey is now living in Denver.

S. G. Hancock, Steep Rock Iron Mines Ltd., Steep Rock Lake, Ont., has been promoted to assistant to the manager. **Walter Bannister** is now general mining engineer.

James I. Craig, formerly of the Bertha Mine Div., New Jersey Zinc Co., has been transferred to Hanover, N. M.

R. A. Young, American Zinc, Lead & Smelting Co., St. Louis, is executive vice president of the newly formed Uranium Reduction Co., Moab, Utah. **J. W. Burgess** of Dumas, Texas, will be in charge of mill construction. **R. F. Hollis**, manager, National Lead Co., Grand Junction, Colo., has been named general manager of the Moab mill. **E. H. Snyder, Jr.**, metallurgist, Combined Metals Reduction Co., Salt Lake City, will assist Mr. Hollis as process engineer. **D. R. Stewart,** geologist, American Zinc, Lead & Smelting Co., Joplin, Mo., will be chief geologist.

Herman Knight, general superintendent, West Kentucky mines, Bell & Zoller Coal Co., Madisonville, Ky., has resigned to go into uranium mining in the West. He is succeeded by **Eugene T. Moroni,** formerly of the Chicago, Wilmington & Franklin Coal Co., Waltonville, Ill.

John R. Rand, resident geologist for Copper Range Co. and White Pine Copper Co., has resigned to enter private consulting practice, with an office at 482½ Congress St., Portland, Maine. After graduating from Harvard College in 1949, Mr. Rand was employed by St. Joseph Lead Co. in British Columbia, Missouri, and Quebec.

PERSONALS

Frank J. Lanza is geologist, Appalachian Sulfides, South Strafford, Vt. Mr. Lanza is doing exploratory work in Maine. He was geologist, Magma Copper Co., Superior, Ariz., for more than six years.

William H. Mott, manager, General Electric Co., Butte, Mont., has been promoted to manager, user industries sales, Salt Lake City.

John B. Davies, manager of industrial sales, Mine Safety Appliances Co., Pittsburgh, was elected president of the Industrial Safety Equipment Assn. at the group's recent annual meeting.

W. W. MUEHL

Wallace W. Muehl, chief engineer, Franklin Baker Co., a subsidiary of General Foods Corp., Manila, P. I., has been elected executive vice president of the Philippine Society of Mechanical Engineers for 1955 to 1956. Prior to going to the Philippines, Mr. Muehl spent several years as a district engineer for the Link-Belt Co. in western Pennsylvania, Nevada, Arizona, and southern California. Before going to Pennsylvania he was a mill superintendent in Bolivia for Patino Mines & Enterprises.

Bahngrell W. Brown has joined the faculty of the Montana School of Mines, Butte.

D. C. Snyder is vice president, C. H. Sprague & Son Co. Inc., New York. Mr. Snyder was vice president, Bell & Zoller Coal Co., Mount Hope, W. Va.

Harry C. Chellson, Pittsburgh district manager, *Engineering & Mining Journal* and *Coal Age*, has been named New York district manager for both publications.

Richard W. Lottridge, assistant to vice president, Combined Metals Reduction Co., has been appointed assistant to the president, Federal Uranium Corp., Salt Lake City.

C. Taylor Marshall has been promoted to general manager of the newly consolidated Coke & Iron Div., Pittsburgh Coke & Chemical Co., Pittsburgh. Mr. Marshall was first employed by the company in 1943. He subsequently served in the U. S. Air Force and returned to the company in 1950. In 1953 Mr. Marshall became assistant to the plant manager. He is a member of the Executive Board of the Blast Furnace and Raw Materials Committee of the AIME.

Charles H. Bowen is geologist, U. S. Atomic Energy Commission, Grand Junction, Colo. Prior to joining the AEC Mr. Bowen was research engineer with the Ohio State University Engineering Experiment Station for eight years.

David Heiman is industrial engineer, U. S. Metals Refining Co., Carteret, N. J. Mr. Heiman was graduated from Harvard Business School in June with an M.B.A. degree.

Allen T. Cole, manager, Florida Phosphate Div., Davison Chemical Co., a division of W. R. Grace & Co., Bartow, Fla., has been named manager of the newly formed atomic developments dept., with headquarters at Baltimore. Mr. Cole joined Davison in 1946.

A. B. Drescher has joined the ore dept., Lone Star Steel Co., Lone Star, Texas. He was with Union Pacific RR Co., Oil & Mineral Development, Laramie, Wyo.

John A. Bowsher is the western Montana representative of the U. S. Bureau of Mines with headquarters at the Montana School of Mines, Butte. Mr. Bowsher was formerly in the Spokane office of the USBM.

Elza Fain Burch, coal preparation engineer, Red Jacket Coal Co., Red Jacket, W. Va., is now engineer for the company's Northern Sales Div., Columbus, Ohio.

James H. Eastman, Canadian Exploration Ltd., Salmo, B. C., has been transferred to Pato Consolidated Gold Dredging Ltd., El Bagre, Antioquia, Colombia.

George D. Dickey, American Transportation Corp., New York, is now with the Conkey Equipment Div., Chicago Bridge & Iron Co., New York.

Leo M. Abell has been appointed research engineer, concentrator research dept., Phelps Dodge Corp., Morenci, Ariz. Mr. Abell was mill superintendent, Cyprus Mines Corp., Nicosia, Cyprus.

Jens Jensen has been elected president, Pend Oreille Mines & Metals Co., Spokane. Mr. Jensen has been an officer and director of the company since it was organized in 1929. Mr. Jensen will retain his position as treasurer.

R. E. BYLER

Raymond E. Byler has been appointed business manager, Western Laboratories Div., Arthur D. Little Inc., San Francisco. This company recently acquired the Research & Development Div. and laboratories of the Merrill Co. Mr. Byler, who was responsible for technical activities, joined Merrill Co. in 1935. His professional experience includes many years in the metallurgical and chemical process fields. During World War II he was engineer in charge of process development and plant design for Metals Inc.

Joseph Warren Barker was nominated for the office of president for the year 1955 to 1956 of the American Society of Mechanical Engineers during the Diamond Jubilee semiannual meeting in Boston. Mr. Barker is chairman of the board and president, Research Corp., New York, and chairman of the board, Research-Cottrell Inc., New York.

Paul W. Allen, Cyprus Mines Corp., Los Angeles, has been elected vice president and general manager of Pima Mining Co., Tucson, Ariz.

Victor Phillips has joined Christopher Coal Co., Osage, W. Va. Mr. Phillips was formerly with the Industrial Engineering & Construction Co. Inc., Fairmont, W. Va.

Wayne R. Zwickey is exploration geologist, The New Jersey Zinc Co., Platteville, Wis. Mr. Zwickey was employed by the U. S. Army Corp. of Engineers, Jacksonville, Fla.

W. B. Hall is metallurgist with Cyprus Sulphur & Copper Co. Ltd., Limni mines, Polis, Cyprus. He was senior metallurgist with Nchanga Consolidated Copper Mines Ltd., Chingola, Northern Rhodesia, and had been with this company for eight years.

Gary R. Rice has accepted a job as engineer with the Hecla Mining Co., Wallace, Idaho.

Arthur G. Blucher, Jr., is with Atlas Toledo Project, Cebu City, P.I. Mr. Blucher was with San Manuel Copper Co., San Manuel, Ariz.

Max Krey and **E. J. Schuh,** geological consultants, have opened offices in the Commerce Bldg., 127 N. 4th St., Grand Junction, Colo. Prior to becoming a consultant, Mr. Krey was with Sinclair Oil & Gas Co., Casper, Wyo., and Aerial Geologic Surveys, Denver. He received a B.S. in geology from Kansas State College and did graduate work at the University of Colorado. Mr. Schuh, who was also with Aerial Geologic Surveys, received a B.S. in professional geology from University of Wyoming.

Jacob Blecheisen, president, Rosiclare Lead & Fluorspar Mining Co., Rosiclare, Ill., has been appointed by **Secretary of the Interior Douglas McKay** to serve on the Fluorspar Industry Advisory Committee.

Gordon Weller has been named advertising manager, Climax Molybdenum Co., New York. He was formerly public relations director for the company's western operations at Climax, Colo. Prior to joining Climax in 1953, Mr. Weller was public relations director for Colorado Oil & Gas Industries. He is succeeded at Climax by **Donald Stephens.**

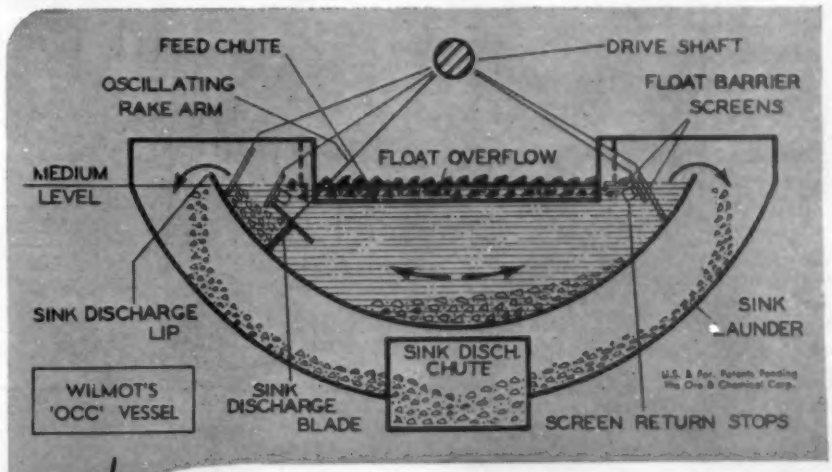
A. E. Adami, dean and vice president, Montana School of Mines, Butte, has been reappointed by **Gov. J. Hugo Aronson** to the Montana Board of Registration for Civil Engineers and Land Surveyors for a five-year term.

Rev. James B. Macelwane, dean, St. Louis University, Institute of Technology, has been appointed chairman of an 11-member American technical panel on seismology and gravity which is planning the first geophysical exploration of Antarctica.

David B. Dill, Jr., formerly of Cía. Minera de Peñoles, Monterrey, Mexico, is now with St. Joseph Lead Co., Edwards, N. Y.

George R. Putnam has retired from the vice presidency of Utah Construction Co., Salt Lake City. Mr. Putnam joined the company at Ogden, Utah, in 1934 as project manager and in 1950 was appointed vice president and district manager of the Intermountain Area. Mr. Putnam started his career in 1905 with the Great Northern Ry., St. Paul. From 1907 to 1934 he held many positions, including that of foreman, Siems, Carey & Helmers, St. Paul, general superintendent and project manager, Grant Smith & Co., Spokane, and project manager, Lawler, Woodward of Seattle.

W. H. Goodrich, general manager, Chino Mines Div., Kennecott Copper Corp., Hurley, N. M., has been named vice chairman, Economic Development Commission by **Gov. John F. Simms.** The purpose of the commission is to evaluate resources, gather basic information, and promote industry in New Mexico.



Look into **WILMOT'S *New* HM VESSEL**

Noteworthy advantages of this advanced-type unit include: (1) entire separating process is performed with only the mechanism and power required for lifting the sink from pool; (2) permits continuous visual inspection; (3) few moving parts; (4) requires little floor space. We furnish single replacement units or complete systems for coal or ore. Send for bulletin.

WILMOT ENGINEERING CO. HAZLETON, PENNA.

Richard M. Foose, formerly of Franklin & Marshall College, Lancaster, Pa., is now with the geology dept., Stanford University, Stanford, Calif.

David L. Moore of Rosario Exploration Co., Grand Junction, Colo., has joined the Exploration Div., The American Metal Co. Ltd., New York.

Stanley A. Gudmundsen has been promoted to master mechanic, Bingham Canyon mine, Kennecott Copper Corp. Utah Copper Div. Mr. Gudmundsen joined the company in 1924 and was mine shop foreman until 1947 when he became assistant master mechanic. He succeeds **George W. Bolman** who has retired after 46 years' service.

Cornelius F. Kelley, former chairman of the board, The Anaconda Co., has been awarded an honorary degree of Doctor of Laws by Fordham University.

Norman B. Holter, president, Holter Foundation, Helena, is president-elect of the Society of Nuclear Medicine at Spokane.

Arthur L. Bailey is development engineer, International Minerals & Chemical Corp., Bartow, Fla.

B. D. Thomas, David C. Minton, Jr., and **John S. Crout,** have been appointed vice presidents, Battelle Memorial Institute, Columbus, Ohio.

O. F. HOLMGREN

Oscar F. Holmgren, executive vice president, U. S. Vanadium Co., New York, has been appointed vice president of Union Carbide Nuclear Co., a new division of Union Carbide & Carbon Corp. **Lyman A. Bliss** and **Clark E. Center** are also vice presidents, and **Kenneth Rush,** a vice president of UC&C, is president of the new division.

D. P. Morton, chief rating commissioner, Chesapeake & Ohio Ry Co., Huntington, W. Va., has retired. Mr. Morton joined the company in 1920 as allotment commissioner and became chief rating commissioner in January 1934.

HERE'S PROOF OF REAL DRILLCO BIT PERFORMANCE

Bit No. AR-28 Footage: 469 ft.
Bit No. AR-33 Footage: 425 ft.
Bit No. AV-2 Footage: 455 ft.
Bit No. V-60 Footage: 624 ft.
Bit No. V-61 Footage: 674 ft.
DRILLCO
DRILL PRODUCTS

The illustrated EX Standard Drillco Diamond Impregnated Bits were used in exploratory drilling in *Green Stone, Iron Ore* and *Jasper*. Using a standard drill rig with either hydraulic or screw feed, a total of 2647 feet was drilled with the bits pictured above, to obtain an average of 32¢ per foot. Here is proof of the economical drilling obtainable with DRILLCO Diamond Impregnated Bits.

Send for Drillco Catalog

Pioneering in Diamond Impregnated Products Since 1932

DIAMOND PRODUCTS INC. 339 Prospect Street, Elyria, Ohio

B. J. Herron, assistant to the president, Thor Power Tool Co., Chicago, has gone to Australia and New Zealand as the company's representative.

William H. Swayne is chief geologist for South America for The Anaconda Co., with headquarters at the Chile Exploration Co. in Chuquicamata, Chile. Mr. Swayne was exploration geologist for Cía. Sud Americana Exploradora de Minas, Santiago, Chile.

Arthur Bevan, principal geologist, Illinois State Geological Survey since 1947, has retired. Mr. Bevan will resume field studies in the Appalachians of west-central Virginia. From 1929 to 1947 Mr. Bevan was state geologist of Virginia.

Robert M. Dreyer has been appointed chief geologist, Kaiser Aluminum & Chemical Corp., Oakland, Calif.

L. E. Shaffer, professor of mining, University of California, Berkeley, recently returned from France and French Morocco. This was his second trip in six weeks. The first, in June, took him to France, Italy, Austria, and Morocco. Both were professional examination trips to mining properties in those countries.

K. B. Platt is process metallurgist, E. I. du Pont de Nemours & Co., in Florida. Mr. Platt was formerly assistant mill metallurgist, Braden Copper Co., Sewell, Chile.

John G. Morrow is research metallurgist, Quebec Metallurgical Industries Ltd., Ottawa, Ont. Mr. Morrow was formerly with the Steel Co. of Canada Ltd., Hamilton, Ont.

Marvin H. Pond has been appointed technical director for Keystone Ridgeway Corp., Gettysburg, Pa. Mr. Pond was assistant chief research metallurgist, Olin Mathieson Chemical Corp., New Haven, Conn. Mr. Pond has had wide experience in the development of various ceramic operations.

John A. Plimpton is vice president, Crusher Engineering Div., Poor & Co., Philadelphia. Mr. Plimpton was formerly with the Pennsylvania Crusher Co.

Frederick F. Frick, research engineer, Anaconda Reduction Works, The Anaconda Co., has retired after 40 years' service. He is succeeded by **Francis L. Holderreed** who has been assistant engineer to Mr. Frick since 1953.

James T. Finlen, western general counsel, The Anaconda Co., Butte, Mont., has been appointed a member of the National Resources Committee of the U. S. Chamber of Commerce.

Mostyn G. Grant is now with Cyprus Mines Corp., Tucson, Ariz. He was formerly in charge of exploration work for the Coronado Copper & Zinc Co., a subsidiary of Cyprus Mines, in Butte.

Robert C. Wilson, White Pine Copper Co., White Pine, Mich., is smelter superintendent, San Manuel Copper Corp., San Manuel, Ariz.

Peter A. Cain has joined Sherritt Gordon Mines Ltd., Lynn Lake, Man., as mine superintendent. Mr. Cain was with O'Okiep Copper Co., Nababiep, C.P., South Africa.

W. M. Fassell has been appointed director of research, Howe Sound Co. Mr. Fassell was formerly associate professor of metallurgy at the University of Utah. A temporary laboratory in Salt Lake City under Mr. Fassell's direction has been established by Calera Mining Co., a subsidiary of Howe Sound. **H. A. Pearse,** vice president of Howe Sound Co., has announced that the company will erect a research and experimental center in Salt Lake City.

F. R. Thompson is mine manager, Canam Copper Co. Ltd., Hope, B. C. Mr. Thompson was formerly general superintendent, Sheep Creek Gold Mines Ltd., Mineral King Property.

C. S. Wiedman, product and process development engineer, Carboloy Dept., General Electric Co., Detroit, has been appointed manager of carbide products development engineering. Mr. Wiedman has been with General Electric since 1947. He joined the Carboloy Dept. shortly after completing the company's chemical and metallurgical training program in 1948. Mr. Wiedman was graduated from the University of Michigan.

K. L. COOK

Kenneth L. Cook has been promoted to full professor and head, geophysics dept., University of Utah, Salt Lake City.

Hubert C. Smith has been appointed director of product engineering, Colorado Fuel & Iron Corp., Claymont, Del. Mr. Smith was vice president in charge of research, Great Lakes Steel Corp., Detroit, and had been with this company since 1936. He is a graduate of McMaster University, Hamilton, Ont., and demonstrated and lectured at the University of Toronto graduate school.

John H. Spillane, vice president, Electro Metallurgical Co., a division of Union Carbide & Carbon Corp., New York, is now with Western Foundries, Denver.

George Deshler is superintendent of mills, American Smelting & Refining Co., Mullan, Idaho. Mr. Deshler succeeds **George Price,** who has retired after nearly 39 years of service with Asarco.

Harry W. Bradbury, president, Mid-West Utilities Coal Corp., Sparta, Ill., has been elected president, Lehigh Valley Coal Co., Kingston, Pa.

Edgar C. Weichel, vice president, Hudson Coal Co., Scranton, Pa., and member of the Anthracite Board of Conciliation, has retired from active affiliation with the industry. Mr. Weichel began his career in the coal industry in 1903 in the engineering dept. of the Pennsylvania Coal Co. He joined the Hudson Coal Co. in 1923 as mining engineer and was elected vice president in 1950.

Otto Herres, vice president, Combined Metals Reduction Co., Salt Lake City, has been named to serve a new term on Utah's Employment Security Review Board.

Hugh Douglas is geologist, American Overseas Petroleum Ltd., New York. Mr. Douglas was with Texas Gulf Sulphur Co., New York.

M. L. Alley, formerly general manager, Gauley Mountain Coal Co., Ansted, W. Va., has joined Jewell Ridge Coal Corp., Tazewell, Va.

Charles G. Evensen is assistant professor, geology dept., Texas Western College, El Paso. Mr. Evensen was formerly with the U. S. Atomic Energy Commission, Kayenta, Ariz., and at Grand Junction, Colo.

Frank E. Cash, U. S. Bureau of Mines, Washington, D. C., has retired after 33 years' service in the mining and safety divisions. During this time Mr. Cash has worked in Pittsburgh, Birmingham, Duluth, and College Park, Md., and since 1950 in Washington, D. C. Mr. Cash will live in Panama City, Fla.

Edward C. Burdick, director, patent dept., Dow Chemical Co., for the past 18 years, has retired after nearly 40 years' service with the company. Mr. Burdick will continue to serve the company as a consultant. He is succeeded by **William M. Yates,** assistant director, who has been with the company for 20 years.

Dorner T. Schueler, Jr., mining engineer, Helmke, Thomas & Janssen, San Francisco, is now at the Lambert mine, Magalia, Calif.

Herbert Geittman, Jr. and **J. Richard Milliken** have joined the Metallurgical Development Div., Climax Molybdenum Co.

F. J. DUNKERLEY

F. J. Dunkerley has been named assistant general manager of the Rolle Mfg. Co., Lansdale, Pa. Mr. Dunkerley has served the company as a metallurgical consultant for five years. In 1954 he joined Rolle in an administrative position and since that time has been appointed to the post of vice president and general manager of Rolle Research & Testing Inc., Hatfield, Pa. Mr. Dunkerley spent the first four years of his professional career at Battelle Memorial Institute. He then went to the University of Pennsylvania as professor of metallurgy. Mr. Dunkerley is a graduate of the Carnegie Institute of Technology.

Noel Frost has joined Lorac Service Corp., Houston. Mr. Frost was with Seismograph Service Corp. of Mexico, Mexico, D.F.

D. M. Wade, Jr., is now with St. Joseph Lead Co., Leadwood, Mo. Mr. Wade was assistant general superintendent at the company's El Aguilar operations, Province of Jujuy, Argentina.

A. G. Roach has resigned as mill superintendent, Malartic Gold Fields Ltd., Halet, Que., and is now with Algom Uranium Mines Ltd., Algoma Mills, Ont.

William J. Waylett is now with the International Cooperation Administration as chief, Mineral Resources Div., U. S. Operations Mission to Israel, headquartered in Tel Aviv. Mr. Waylett was formerly chief, Technical Services Branch, Div. of Raw Materials, AEC, Washington, D. C.

F. William Wessel of the U. S. Bureau of Mines, Albany, Ore., has been transferred to Minneapolis.

Joseph W. Berg, Jr., is assistant professor, geophysics dept., University of Utah, Salt Lake City. Mr. Berg was assistant professor of geophysics, University of Tulsa, Okla.

Harry J. Wolf, mining and consulting engineer, New York, was in Arizona and California during May and July investigating tungsten, uranium, and sulphur deposits.

OBITUARIES

Edwin Letts Oliver

An Appreciation by
T. B. Counselman

On August 28th the American Institute of Mining and Metallurgical Engineers lost one of its most distinguished members, Edwin Letts Oliver, who died suddenly at his summer home in Lake Tahoe.

Mr. Oliver was a Life Member of AIME, having joined in 1902, and was a Member of the Legion of Honor Class of 1952. He was a past Chairman of the San Francisco Section, 1939, was elected a Director of the Institute in 1953, and was the recipient of the James Douglas Gold Medal for distinguished achievement in nonferrous metallurgy in 1955.

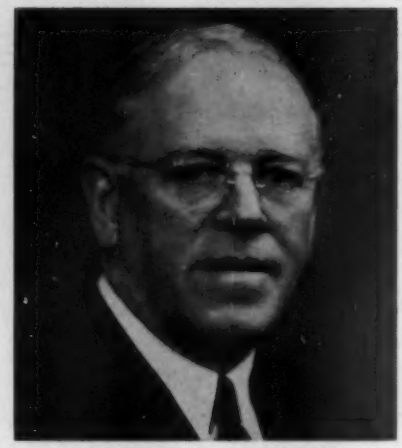
Edwin Letts Oliver was born in 1878, graduated from the College of Mines of the University of California in 1900, and received the honorary degree of LL. D. from that same university in 1945. His career in metallurgy was long and distinguished. Soon after graduation, he joined North Star Mines in Grass Valley, Calif., and became involved in the improvement of gold recovery and decreasing of tailings losses. This led to the development of the Oliver continuous filter, the first successful unit of its type.

After conducting his filter business at night and on weekends for two years, while continuing as metallurgist of the North Star Mines, Mr. Oliver finally resigned from the latter position and in 1910 formed the Oliver Continuous Filter Co., with offices in San Francisco, to market his inventions.

Through the years, various other types of filters and auxiliary equipment were invented or acquired and in 1925 the Oliver United Filters Inc. was formed, with subsidiary companies in England and France. Mr. Oliver continued as president of this company until Dec. 31, 1954, when it was merged with The Dorr Co. to form Dorr-Oliver Inc., of which he became one of the two founder-chairmen.

Mr. Oliver was active in many phases of metallurgy besides the operation of the company he founded. In his early days, he designed and built several cyanide plants in California and operated a number of gold mines and mills. He was one of the founders of the famous Idaho-Maryland mine, for many years one of the largest of the U. S. gold producers.

Besides his active interest in AIME, Mr. Oliver was a member of the Mining and Metallurgical Society of America; Chemical, Metallurgical, and Mining Society of South Africa; Society of the Golden Bear; Sigma Xi; Delta Upsilon; and Sigma Gamma Upsilon, as well as the Engineers' Club and Bohemian Club, both of San Francisco.



EDWIN LETTS OLIVER

Mr. Oliver is survived by his widow, the former Minnie Griffin Walker, to whom he was married in 1905; two sons, William L. and Edwin Letts, Jr.; and two daughters, Mrs. Fred L. Greenlee and Mrs. Adrian Shannon.

Arthur A. De Melik (Member 1936), mining engineer, died June 16, 1955 in New York where he had resided for 25 years. Mr. De Melik was born in Russia in 1887 and received a diploma in mining engineering in 1909 from the Mining Academy of Freidberg, Germany. For the next three years he was superintendent of construction for a mile-long tunnel for John Northon Griffits Ltd., London, and from 1912 to 1914 he was superintendent of oil fields in Binagadi, Baku. Following service in World War I as a captain in the British Army, Mr. De Melik was with the Ste Anonyme de Gyps in France for four years, before joining Union Carbide Co. in New York in 1925. He was later employed by General Chemical Co., New York, and by Arthur G. McKee & Co., Cleveland. While with this firm Mr. De Melik was the engineer in charge of research and development of one of the largest iron deposits in the world at Magnitogorsk, Russia. He was later president and manager, Deer Trail Tungsten Corp., Ely, Nev.

Paul Georges Leroy

An Appreciation by
T. E. Gillingham

Paul Georges Leroy (Member 1953) died in the crash of a Sabena airliner on Mount Terminillo, near Rieti, Italy, on Feb. 13, 1955. To those of us who knew Paul, his sudden and tragic passing was a dreadful shock.

In his 27 years on earth, Paul Leroy had accomplished much, and by his quiet friendliness, extreme modesty, and gentlemanly qualities had endeared himself to his friends and associates alike.

Paul was born at Watermael-Boitsfort, Belgium, on Oct. 28, 1927, the fifth child of Mr. Julien Leroy, now president of African Metals Co., and Mrs. Leroy. When World War II engulfed their homeland, the Leroy family, excepting two of Paul's older brothers who served in the R.A.F., found refuge in New Rochelle, N. Y. Paul attended Iona Preparatory School and, though his college career was interrupted by a year's service in the American Army in Korea, he was graduated with high honors from Iona College, New Rochelle, in June 1949. Thereupon, he chose economic geology as his life work and in the fall entered the graduate school of Columbia University. In 1953 he was awarded his Ph.D. degree. His doctorate thesis, "Correlation of Copper Mineralization With Hydrothermal Alteration in The Santa Rita Porphyry Copper Deposit, New Mexico," was published in the August 1954 issue of the *GSA Bulletin*. The paper has evoked many favorable comments and requests for reprints are still being received.

As a logical consequence of the excellence of his thesis work at Santa Rita, Paul returned to New Mexico as a Kennecott geologist. He mapped and studied the zinc orebodies around the Chino pit, and when that work was done he was transferred to Kennecott's exploration subsidiary, Bear Creek Mining Co., Eastern District. At the time of his death, he was on a company mission to Africa.

Meanwhile Paul became a naturalized American citizen, and in June 1951 in Brussels, he married Madeleine Seynaeve, daughter of the Belgian Minister to Lebanon. A son and a daughter graced their marriage, and at the time of Paul's death, a third child was expected.

Though Paul has gone from us, we shall long cherish our memories of his fine accomplishments and exemplary character.

Derwood A. McKinley (Member 1953) drowned May 27, 1955 in Siscoe Lake, Val d'Or, Que., in a vain effort to rescue two others. He was a metallurgist with East Sullivan Mines Ltd., Val d'Or. Mr. McKinley was born in Cobalt, Ont., in 1930 and was graduated in 1952 from Provincial Institute of Mining, Haileybury, Ont. He then spent two years in Mexico as mill metallurgist with the Santa Barbara Unit, American Smelting & Refining Co. On returning to Canada Mr. McKinley first worked as a metallurgist for Opemiska Copper Mines Ltd. He was a member of the Canadian Institute of Mining and Metallurgy.

Martin C. Messner

An Appreciation by
Kurt Ruckwardt, Tel Fulmor,
and R. G. Bowman

Martin C. Messner, Member since 1941, superintendent of the Phosphate Div. of The Anaconda Co., died May 31, 1955 at Anaconda,

Necrology

Date Elected	Name	Date of Death
1908	Charles P. Berkey	Aug. 22, 1955
1929	Robert B. Campbell	Aug. 16, 1955
1934	H. J. French	Aug. 17, 1955
1934	J. O. Greenan	July 23, 1951
1918	Hugo E. Hanser	July 14, 1955
1945	Carleton C. Hascall	June 1, 1955
1952	John D. Hysong	July 23, 1955
1915	Estey A. Julian	Aug. 2, 1955
1937	Frank L. Kennicott	June 29, 1955
1920	Lewis P. Larsen	July 14, 1955
1934	Donal F. McCarthy	May 10, 1955
1902	Edwin Letts Oliver	Aug. 28, 1955
1891	Frederick D. Power	June 29, 1955
1914	Gar A. Roush	Aug. 16, 1955
1946	Everett S. Shaw	June 30, 1955

Mont., of a heart attack while playing golf at the Country Club. Mr. Messner was a widely known metallurgical engineer, having been associated with Anaconda both in American and European properties and with the defense program during World War II.

He was born on Dec. 25, 1897 at Houghton, Mich. His parents, the late Mr. and Mrs. Martin C. Messner, were natives of the Michigan copper country. He graduated from the Houghton County High School with honors in 1916 and at the outbreak of World War I enlisted with the 32nd Div. and served for two years, of which a large part was in active combat in France and Germany.

Following his discharge from the army he entered Michigan College of Mines at Houghton and received his degree as Engineer of Mines in September of 1922. He taught mathematics in the Houghton High School and did some exploration work for a Canadian mining company until April of 1923, when he joined the staff of The Anaconda Co. at Anaconda as assisting research engineer.

In November of 1925 he was chosen as one of seven engineers under the leadership of the late Chauncey Berrian, manager of mines for The Anaconda Co., to make an exploratory investigation of the German Von Giesche Mining Co. in Upper Silesia, Poland. When The Anaconda Co. assumed management of this vast property, then known as the Giesche Spolks Akcyjna organization of Kattowice, Poland, he was assigned to the position of mill superintendent. During the 14 years he spent with that organization he was given a progression of metallurgical positions and was metallurgical manager of the company when World War II started and the Americans were forced to leave Poland in early September 1939. He spent several months in Rotterdam, Holland, prior to returning to America. During his European career he also served as a consultant for companies in Germany, Sweden, Denmark, and Yugoslavia.

In January 1940 he returned to the research dept. of The Anaconda Co. in Anaconda and for a time was an engineer in the phosphate dept. When America entered World War II and the Government decided to open the chrome mines at Dean, Mont., he was selected as mill superintendent for that large defense project. From February 1941 until January 1944 he took a leading part in the building and operation of the strategic defense plants at the Ben Bow and Mouat mine properties.

He returned to the research dept. at Anaconda and was named superintendent of the manganese kiln in the fall of 1944. He conducted the research investigation for the ferromanganese plant, doing much of this work at The Anaconda Co. plant in Great Falls. He became assistant research engineer in Anaconda until July 1949, when he was named superintendent of the manganese and ferromanganese plants. In February of 1950 he was selected to be superintendent of the Phosphate Div. In this position he originated and developed a number of new and timely improvements in process and equipment.

He was married to the former Florence L. Conrad of Anaconda in Berlin, Germany, on June 23, 1927. In addition to his widow he is survived by a daughter, Mrs. Charles A. Purseglove, of Milwaukee; a son, Lt. Martin E. Messner, also a graduate engineer, now stationed at Great Falls Air Force Base in Montana; and a granddaughter, Elizabeth Ann Purseglove, of Milwaukee. He was deeply devoted to his home and family.

In addition to his membership in the AIME, in which he took a most active part, he was a member of Tau Beta Pi, engineering honorary fraternity, the American Legion, and the Catholic Church. An ardent sportsman and hobbyist, the outstanding traits for which Marty will be remembered with affection by all who knew him were his infectious enthusiasm and the intensity and vigor with which he approached all situations.

Marty Messner, with his interesting career and wide experience, was an outstanding engineer. He had an unceasing interest in encouraging and helping young engineers in their profession. His gift of friendliness and enthusiasm, his rich sense of humor, his personal integrity, and his professional competence inspired the respect of his associates and won the esteem and affection of his many friends.

Reginald H. Parsons (Rocky Mountain Member 1928) died June 9, 1955 in Seattle after a long illness. A well known financier and philanthropist, Mr. Parsons was born in 1873 in Flushing, N. Y., a descendant of John Bradford, first Governor of Massachusetts. He worked as a real estate man and mining broker before heading Parsons Investment Co. in Seattle and Pinnacle Packing Co. and Hillcrest Orchard, Medford, Ore. Among his many other activities, Mr. Parsons was a national executive of the Boy Scouts of America, president of the Seattle Chamber of Commerce, and president of the Seattle Community Fund.

SuperDuty
DIAGONAL DECK
No. 6
CONCENTRATOR
TABLE
DEISTER
DIAGONAL
DECK
OVERSTROM
SuperDuty ® Concentrates Minerals
with Unmatched Efficiency
Mineral pulps are handled most efficiently on the SuperDuty DIAGONAL-DECK® Concentrating Table. Exclusive construction features combine to deliver exceptionally high grade concentrates with minimum loss to the tailings while, at the same time, greatly reducing the middling load for recirculation. You are assured greatest economy and efficiency. Send for Bulletin 118-B.
THE DEISTER CONCENTRATOR COMPANY
The Original Deister Co., Incorporated 1906
923 Glasgow Ave. Fort Wayne, Ind. U.S.A.

NEW! for U_3O_8
1955 MODEL DR-299
NUCLIOMETER
Jms
TRC
TRS
$545.00 IN USA
3 INSTRUMENTS IN ONE... NO PRICE CHANGE!
Check these unique features!
THREE IN ONE: Probe Geiger—Radiometric Assays—Ultra-sensitivity for low level radiation.
ALOFT OR ON WHEELS: Low level anomalies at a glance. 4 time constants, 6 ranges from 20.0 to 0.01 MR/HR, for surface or carborne work!
HOT OR COLD: 6 miracle Bismuth, 18 powerful Geiger tubes defy temperature extremes. No more heat failure of delicate crystals and circuits!
COMPLETE: Instrument includes rugged leather case, probe, assay-sample holder. Nothing else to buy! Pack weight, just 10½ lbs.
GUARANTEED FOR SURE: Take 10 days to prove it! Return in new condition for cheerful refund if you don't think this instrument is absolute tops!
May we bid your exploration, ore finding or management job? Airborne methods & photogeology by mining geologists with 30 years cold-dollar experience. Open pit or underground exploitation from claim to concession. Write or wire for details.
STRATEX INSTRUMENT COMPANY, INC.
3515A Sunset Blvd. Los Angeles 26, USA
EXPLORATION COMPANY

MEMBERSHIP

Proposed for Membership
Mining Branch, AIME

Total AIME membership on July 31, 1955 was 23,194; in addition 1903 Student Associates were enrolled.

ADMISSIONS COMMITTEE

P. D. Wilson, Chairman; F. A. Ayer, Vice-Chairman; A. C. Brinker, R. H. Dickson, T. D. Jones, F. T. Hanson, Sidney Rolle, O. B. J. Fraser, F. T. Sisco, Frank T. Weems, R. L. Ziegfeld, R. B. Caples, F. W. McQuiston, Jr., A. R. Lytle, H. R. Wheeler, L. P. Warriner, J. H. Scaff.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Alabama
Birmingham—Daniel, Jay R. (J)
Arizona
Inspiration—Kuhn, John G. (J)
Tucson—Anderson, William, Jr. (M)
California
Foresthill—Wilson, William E. (M)
Palo Alto—Madison, Frank J. (M)
San Francisco—Winn, Burdett A. (M)
Torrance—Burns, Thomas E. (M)
Colorado
Denver—Coffey, Robert C. (M)
Florida
Lakeland—Bart, Roger (M)
Orlando—Deal, Troy M. (M)
Idaho
Montpelier—Darden, Taylor (M)
Illinois
Lombard—Komarek, Karl R. (C/S—A-M)
Louisiana
Port Sulphur—Jones, Emmett P. (J)
Massachusetts
Brookline—Ravreby, Fred A. (J)
Montana
Boulder—Field, William E. (M)
Butte—Becker, Erwin W. (M)
New Hampshire
Claremont—Osgood, Robert C., Jr. (M)
New Mexico
Carlsbad—Smith, W. Aubrey (M)
Vanadium—Macloon, Louis O. (A)
Vanadium—Waidler, Walter C. (R. C/S—S-M)
New York
New York—Morize, Jacques (J)
New York—Reiss, Meyer M. (M)
Oregon
Salem—Fretwell, William R. (M)
Salem—Schwarz, Sigmund D. (J)
Pennsylvania
East Pittsburgh—Coen, Ira (M)
York—Duersmith, Leonard J. (M)
Tennessee
Knoxville—Sanford, Alfred F., II (A)
Utah
Cedar City—MacDonald, Graham D., III (M)
Lark—Buehler, Jay K. (J)
Lark—Hall, Harry D. (R. C/S—S-A)
Lark—Partner, Richard W. (A)
Midvale—Wright, Harold E. (R. M)
Salt Lake City—Humphrey, Arthur G. (J)
Virginia
Yorktown—Johnson, Raymond E. (J)
Washington
Spokane—Masters, Edwin S. (R. C/S—A-M)
West Virginia
Fairmont—Basile, Joseph C. (M)
Africa
Belgian Congo, Bukavu—Fournier, Clement H. (M)
Gold Coast Colony, Tarkwa—Woods, Edward H. (M)
Northern Rhodesia, Chingola—Mantell, Keith E. (C/S—J-A)
South Africa, Pretoria—Soine, Frederick E. A. (M)
France
Auby—Lamarche, Alfred M. C. J. (M)
Hong Kong
Kowloon—Abbass, Gerald (M)
India
Nagpur—Bhattacharya, S. K. (M)
Mexico
Concepcion—Millan, Julio R. (A)
Pakistan
Quetta—Shafiuddin, Mohammed (M)
Peru
Cerro de Pasco—Flores C., Julio E. (A)

Professional Services

Appraisals, Assayers, Chemists, Construction, Consulting, Designing — Geophysicists, Drilling, Management, Metallurgical, Reports, Valuations

Space limited to AIME members or to companies that have at least one member on their staffs. One inch, $40 per year; half inch, $25 payable in advance.

ADAIR, BAILEY & VAN HORN
Minerals Consultants
Geology Mining Ore Dressing
Box 221, Murphy, N. C.

JAMES A. BARR
Consulting Engineer
Mt. Pleasant, Tennessee

Philip J. Baukol Member AIME • ASCE Reg. Mechanical Engr.
DESIGNER OF PLANTS
• INDUSTRIAL • METALLURGICAL •
2731 Valleyside Ave. Berkeley 4, Calif.

BEHRE DOLBEAR & COMPANY
Consulting Mining Engineers and Geologists
11 Broadway New York 4, N. Y.

BLANDFORD C. BURGESS
Registered Professional Engineer
Mining Consultant
Monticello, Georgia

COWIN & COMPANY, INC.
Mining Engineers and Contractors
Shaft & Slope Sinking • Mine Development
Mine Plant Construction
1-18th Street SW,
Birmingham, Ala. Phone 56-5566

R. EMMET DOHERTY
Industrial Dust Engineer
Field Surveys—Analyses—Litigation
85 2nd Avenue, Kingston, Pa.

RENE ENGEL
Consulting Geologist
1222 Blair Avenue
South Pasadena, California
Telephone: ALbany 0012

DAVID LeCOUNT EVANS
Consultant
Mining Geology Petroleum Geology
314 Brown Bldg. Wichita, Kansas
Tel.: AMherst 2-8954 or MUrray 3-6437

GEORGE A. HOCH
Thin Section Technician
Standard and Oriented Sections
Unconsolidated Materials a Specialty
Dept. of Geology
Franklin & Marshall College, Lancaster Pa.

CARLTON D. HULIN
Mining Geology
26th Floor San Francisco 4
Shell Building California

PHILIP L. JONES
Consultant
Mineral Economics & Mineral Dressing
Heavy Media Specialist
405 Miners Bank Bldg. Joplin, Mo.
Tel. MAyfair 3-7161

RAPHAEL G. KAZMANN
Consulting Ground-Water Engineer
Stuttgart, Arkansas

C. P. KEEGEL
Mining and Metallurgical Engineer
Administration Appraisal
Specializing in Management and Consultation in Latin America
707 South 6th St., Las Vegas, Nevada
Telephone 571

KELLOGG KREBS
Mineral Dressing Consultant
564 Market St., San Francisco 4, Calif.

KIRK & COWIN
Consulting • Appraisals • Reports
1-18th Street SW,
Birmingham, Ala. Phone 56-5566

LEDOUX & COMPANY
Chemists Assayers Spectroscopists
SHIPPERS REPRESENTATIVES
Mine Examination Analyses
359 Alfred Ave. Teaneck, New Jersey

JOSEPH T. MATSON
CONSULTING MINING ENGINEER
Examinations—Appraisals
Operations
P. O. Box 170 Santa Fe, New Mexico

CLAYTON T. McNEIL, E. M.
Consulting Mining Engineer
822 Bank of America Bldg.
Tel. GArfield 1-2948
SAN FRANCISCO 4, CALIFORNIA

ARNOLD H. MILLER
Consulting Engineer
Mine, Mill and Industrial Investigations
Improvement Design and Recommendations
Cable: "ALMIL" Tel. Cortlandt 7-0635
120 Broadway New York 5, N.Y.

RODGERS PEALE
Consulting Mining Geologist
315 Montgomery St.
San Francisco 4, Calif.

CHESTER M. F. PETERS
Mining Geology
Evaluations, exploration
and development programs
Colorado Plateau and adjacent areas
930 E. 3rd. South Salt Lake City, Utah

AMEDEE A. PEUGNET
CONSULTING MINING ENGINEER
Telephone MAIN 1-1431
705 Chestnut St. St. Louis 1, Mo.

LUCIUS PITKIN, INC.
Mineralogists
Assayers—Chemists—Spectroscopists
Shippers' Representatives
PITKIN BLDG., 47 FULTON ST., NEW YORK
Cable Address: Niktip

JOHN R. RAND
Consulting Geologist
Mining and Engineering Geology
482½ Congress Street, Portland, Maine
Phone Spruce 4-2602

MILNOR ROBERTS *Consulting Mining Engineer*
The Pacific Northwest,
British Columbia and Alaska
4501 15th Ave., N.E. Seattle, Wash.

WILLIAM J. SHEDWICK, JR.
Mine and Geologic Reports
Mexico and Latin America
New Jersey License 2744-a
Reforma 20-302 Mexico 1, D.F.

CLOYD M. SMITH
Mining Engineer
Mine Examinations
Ventilation Surveys
Munsey Building Washington 4, D.C.

LEO H. TIMMINS, P.Eng.
MINING ENGINEER
Examinations - Reports
Financing of Prospects
Suite 700 1980 Sherbrooke, Montreal
Phone Glenview 2376

GODFREY B. WALKER
Metallurgical Consultant
Mineral Dressing & Extractive Metallurgy
Heavy Media a Specialty
27 Lockwood Drive Old Greenwich, Conn.

O. W. WALVOORD CO.
Mill-Design and Construction
401 High St. Denver 3, Colo.

CLIFFORD R. WILFLEY
Consulting Mining Engineer
2233 Grape St. Denver 7, Colorado

HARRY J. WOLF
Mining and Consulting Engineer
Examinations—Valuations—Management
One Park Place, New York 7, N.Y.
Cable: MINEWOLF Tel: Rector 2-5307

NEWELL G. ALFORD
Consulting Mining Engineer
Coal Property Prospecting, Development, Operation and Valuation
Oliver Building Pittsburgh 22, Pa.

ALLEN & GARCIA COMPANY
42 Years' Service to the Coal and Salt Industries as Consultants, Constructing Engineers and Managers
Authoritative Reports and Appraisals
332 S. MICHIGAN AVE., CHICAGO
120 WALL ST., NEW YORK CITY

B. B. R. DRILLING CO.
National Road West
St. Clairsville, Ohio
Diamond Core Drilling Contractors
Mineral Cores Guaranteed
Foundation Testing

CENTENNIAL DEVELOPMENT CO., Inc.
Eureka, Utah
Tel. 172
Consulting Mining Engineers and Contractors
Shaft Sinking — Tunnel Driving
Mine Development
H. B. Spencer James Quigley

EAVENSON, AUCHMUTY & SUMMERS
MINING ENGINEERS
Mine Operation Consultants
Coal Property Valuations
2720 Koppers Bldg. Pittsburgh 19, Pa.

ENGINEERS ASSOCIATES, INC.
GRAND JUNCTION, COLORADO
Original Uranium Consultants
CHARLES W. YETTER • REGISTERED PROFESSIONAL ENGINEER

FAIRCHILD AERIAL SURVEYS, INC.
Airborne Magnetometer & Gradiometer Surveys, Topographic Mapping, Aerial Photography, and Photographic Mosaics for Mining Exploration.
224 E. 11th St. Los Angeles
30 Rockefeller Plaza New York

ABBOT A. HANKS, Inc.
ASSAYERS-CHEMISTS
Shippers Representatives
624 Sacramento Street
SAN FRANCISCO

HOPKINS EXPLORATION CONSULTANTS
607-320 Bay St. Toronto 1
EM. 4-5642 HU. 9-8375
Branches
Algoma Mills and Timmins, Ont.
Uranium City, Saskatchewan

DIAMOND CORE DRILLING BY CONTRACT
and world's largest manufacturer
Core and grout hole drilling in coal, metal, and non-metallic deposits, both surface and underground.
JOY MANUFACTURING CO.
Contract Core Drill Division
Michigan City, Indiana

KNOWLES ASSOCIATES
Chemical - Metallurgical - Mechanical
ENGINEERS
URANIUM ORE PROCESSING
ECONOMIC STUDIES - MILL DESIGN
19 RECTOR ST. NEW YORK (6) N. Y.

LEGGETTE, BRASHEARS & GRAHAM
Consulting Ground-Water Geologists
Water Supply
Dewatering
Recharging
Salt Water Problems
Investigations
Reports
551 Fifth Avenue, New York 17, N. Y.

ROBERT S. MAYO
Civil Engineer Lancaster, Pa.
Specializing in Concrete Lining of Tunnels, Haulageways and Shafts. Special Equipment for Subaqueous Construction.

R. S. MC CLINTOCK DIAMOND DRILL CO.
Spokane, Wash. — Globe, Ariz.
Diamond Core Drill Contractors
Manufacturer of Diamond Bits and Drilling Accessories

JOHN F. MEISSNER ENGINEERS, INC.
Consulting Engineers
Conveyor Systems
Crushing Plants
Storage Methods
Ship Loading Docks
Materials Handling and Processing Plants
308 W. Washington St. Chicago 6, Ill.

J. B. MORROW
COAL CONSULTANT
Oliver Bldg. Pittsburgh, Pa.

DIAMOND CORE DRILLING CONTRACTORS
Testing Mineral Deposits
Foundation Borings
MOTT CORE DRILLING CO.
Huntington, W. Va.

Frank M. Murphy & Associates, Inc.
DESIGN & CONSTRUCTION ENGINEERS
Specializing in Material Handling Mining Mineral Beneficiation & Chemical Processing
Wesley M. Houston
J. D. Raulerson, Jr.
John C. Yost
Box 271 Bartow, Fla.

PENNSYLVANIA DRILLING COMPANY
PITTSBURGH 20, PA.
DRILLING CONTRACTORS and MANUFACTURERS
We prospect coal and mineral land anywhere in North and South America. Core borings for foundation testing: dams, bridges, buildings, etc.

PRODUCTION AND MANAGEMENT SPECIALIST
ROGER V. PIERCE
Underground Mining Methods, Cost Cutting Surveys—Production Analysis —Mine Mechanization—Mine Management.
808 Newhouse Bldg. Phone 33973
Salt Lake City 4, Utah

M. G. SMERCHANSKI
Consulting Mining Geologist
Registered Professional Engineer
Examinations, Geological Surveys & Development
411 Childs Bldg. Winnipeg, Manitoba
Phone: 926323

SPRAGUE & HENWOOD, Inc.
SCRANTON 2, PA.
Diamond Drill Contractors and Manufacturers
Core borings for testing mineral deposits in any part of the world.

H. L. TALBOT
Consulting Metallurgical Engineer
Extraction and Refining of Base Metals
Specializing in Cobalt and Copper
Room 330, 84 State Street
Boston 9, Mass.

PAUL WEIR COMPANY
Mining Engineers and Geologists
Consultants and Managers
Design and Construction
20 No. Wacker Drive Chicago 6, Ill.

J. W. WOOMER & ASSOCIATES
Consulting Mining Engineers
Modern Mining Systems and Designs
Foreign and Domestic Mining Reports
Union Trust Bldg., Pittsburgh, Pa.
National Bank Bldg., Wheeling, W. Va.

WORLD MINING CONSULTANTS, INC.
Consulting Mining Engineers and Geologists
220 Broadway, New York 38, N. Y.
Worth 2-2934

Coming Events

Oct. 14-15, National Society of Professional Engineers, fall meeting, Peabody Hotel, Memphis, Tenn.

Oct. 17-18, Conference on Mining Research, U. S. Bureau of Mines and Missouri School of Mines, Rolla, Mo.

Oct. 17-19, AIME-IMD, fall meeting, Adelphia Hotel, Philadelphia.

Oct. 17-21, 37th National Metal Congress and Exposition, Hotel Sylvania, Philadelphia.

Oct. 17-21, National Safety Congress and Exposition, Conrad Hilton, Congress, Morrison, and La Salle hotels, Chicago.

Oct. 19-20, ASME-AIME, fuels conference, Neil House, Columbus, Ohio.

Oct. 22, AIME, Adirondack Section, Syracuse, N. Y. Section to attend Syracuse-Maryland football game.

Oct. 24-26, Sixth National Conference on Standards, sponsored by National Bureau of Standards and American Standards Assn., Sheraton-Park Hotel, Washington, D. C.

Oct. 26-28, National Industrial Conference Board, atomic energy in industry, Waldorf-Astoria Hotel, New York.

Oct. 27-29, AIME, Industrial Minerals Div., fall meeting, Hotel Charlotte, Charlotte, N. C.

Oct. 28, Illinois Mining Institute, 63rd annual meeting, Hotel Abraham Lincoln, Springfield, Ill.

Oct. 28-29, Oak Ridge Institute of Nuclear Studies, rare earths in biochemical and medical research conference, Oak Ridge, Tenn.

Nov. 3, AIME, Utah Uranium Subsection, 7:30 pm, Arches Cafe, Moab.

Nov. 7-8, Western Governors Mineral Policies Conference, Sacramento, Calif.

Nov. 11-12, joint meeting Central Appalachian Section, AIME, West Virginia Coal Mining Institute, the Greenbrier, White Sulphur Springs, W. Va.

Nov. 13-18, American Society of Mechanical Engineers, Diamond Jubilee annual meeting, Congress, Hilton, and Blackstone hotels, Chicago.

Nov. 15, AIME, National Open Hearth Steel Committee, Buffalo Section, 6th annual meeting, Royal Connaught Hotel, Hamilton, Ont.

Nov. 17-18, American Mining Congress, Coal Div. Conference, William Penn Hotel, Pittsburgh.

Nov. 27-30, American Institute of Chemical Engineers, annual meeting, Statler Hotel, Detroit.

Dec. 5-9, 25th Exposition of Chemical Industries, Commercial Museum and Convention Hall, Philadelphia.

Dec. 7-9, AIME, Electric Furnace Steel Conference, William Penn Hotel, Pittsburgh.

Dec. 10-16, Atomic Exposition, Public Auditorium, Cleveland. Sponsored by the American Institute of Chemical Engineers in conjunction with the Joint Nuclear Congress.

Feb. 2-3, 1956, Governor's Industrial Safety Conference, 6th annual statewide meeting, Fairmont Hotel. San Francisco. Mineral Extraction Section meets Feb. 2 and 3 at 1:00 pm.

Feb. 20-23, AIME, Annual Meeting, Statler and New Yorker hotels, New York.

Advertisers Index

Allis-Chalmers Mfg. Co., General Machinery Div. 912A-D
Compton Advertising, Inc.

American Cyanamid Co. 896A
James J. McMahon, Inc.

American Manganese Steel Div. American Brake Shoe Co. 896B
Fuller & Smith & Ross, Inc.

Anaconda Co., The ..... *
Kenyon & Eckhardt, Inc.

Arrowhead Iron Works ..... *

Atlas Car & Mfg. Co. ..... *
Howson Adv.

Atlas Copco Compressed Air Engineers 972, 973
Intam Ltd.

Boyles Bros. Drilling Co. 975
Adamson, Buchman & Associates

Braun & Co., C. F. 904A
The McCarty Co.

Brunner & Lay, Inc. ..... *
Norman P. Hewitt Adv.

Bucyrus-Erie Co. ..... *
Bert S. Gittins Adv.

Caterpillar Tractor Co. 920
N. W. Ayer & Son, Inc.

Cleveland Rock Drill Div. ..... *
Hoffman & York, Inc.

Colorado Fuel & Iron Corp. 904
Doyle, Kitchen & McCormick, Inc.

Colorado Iron Works Co. 894
Walter L. Schump, Adv.

Dart Truck Co. ..... *
Carl Lawson Adv. Co.

Davey Compressor Co. ..... *
Palm & Patterson, Inc.

Deister Concentrator Co. 981
Louis B. Wade, Inc.

Denver Equipment Co. 918
Galen E. Broyles Co., Inc.

Detroit Diesel Engine Div. 892
Kudner Agency, Inc.

Diamond Products, Inc. 978
Ritchie & Sattler, Inc.

Diamond Tool Research Co. Inc. ..... *
Preiss and Brown Adv.

Dorr-Oliver, Inc. 905
Sutherland-Abbott Adv.

Dow Chemical Co., The ..... *
MacManus, John & Adams, Inc.

Drullard Co., Howard ..... *

Eimco Corp., The 913
Matsie Co.

Fly Ash Arrestor Corp. ..... *
J. Howard Allison & Co.

Gardner-Denver Co. 896
The Buchen Co.

Hardinge Co., Inc. 898
The W. H. Long Co.

Hercules Powder Co. (Explosives) 906
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) 899
Fuller & Smith & Ross, Inc.

Hewitt-Robins, Inc. ..... *
Fuller & Smith & Ross, Inc.

Houston Technical Laboratories ..... *
Robinson Adv. Agency

Humphreys Investment Co. ..... *
Ed M. Hunter & Co.

Ingersoll-Rand Co. 893
Marsteller, Rickard, Gebhardt & Reed Inc.

International Nickel Co., Inc. 900
Marschalk & Pratt

Jeffrey Mfg. Co. 903
Byer and Bowman

Joy Mfg. Co. ..... Third Cover
Walker & Downing

Longyear Co., E. J. ..... *
Savage-Lewis, Inc.

Mine & Smelter Supply Co. ..... *
Walter L. Schump, Adv.

Mine Safety Appliances Co. ..... Fourth Cover
Ketchum, MacLeod & Grove, Inc.

Murphy & Associates, Inc., Frank M. ..... *

Nagle Pumps, Inc. ..... *
Tri-State Adv. Co., Inc.

Nordberg Mfg. Co. 916, 917
Russell T. Gray, Inc.

Northern Blower Co. 891
Carr Liggett Adv.

Nuclear Instrument & Chemical Co. ..... *
Saunders, Shrout & Assoc.

Osmose Wood Preserving Co. of America *
The Pursell Co.

Phelps Dodge Refining Corp. ..... *
The House of J. Hayden Twiss

Ross Screen & Feeder Co. ..... *

Sheffield Steel Co. ..... *
R. J. Potts-Calkins & Holden Adv.

Spencer Chemical Co. 912
Bruce B. Brewer & Co.

Sprague & Henwood, Inc. ..... *
Frederick B. Garrahan Adv.

Stearns-Roger Mfg. Co. ..... *
Gray & Co., Inc.

Stephens-Adamson Mfg. Co. 904B
Glenn, Jordan, Stoetzel, Inc.

Stratex Instrument Co. 981
Frank Bull & Co.

Sweet's Engrg. Consultants ..... *
Max Goldberg Adv.

Texas Gulf Sulphur Co. 902
Sanger-Funnell, Inc.

Texas Instruments Inc. ..... *
Don L. Baxter, Inc.

Traylor Engrg. & Mfg. Co. 910
The William B. Kamp Co.

Tyler Co., W. S. 975

United States Rubber Co. ..... *
Fletcher D. Richards, Inc.

Universal Atomics Corp. ..... *
Resnick and Katz Inc.

Vulcan Iron Works ..... *
Walter L. Schump, Adv.

West End Chemical Co. ..... *
Norton M. Jacobs Adv.

Western Machinery 911
Boland Associates

Westinghouse Air Brake Co. ..... *
Hoffman & York, Inc.

Wheel Trueing Tool Co. 897
Clark & Bobertz, Inc.

Wilfley & Sons, Inc., A. R. ..... Second Cover
Ed M. Hunter & Co.

Wilmot Engineering Co. 977
Wilbur A. Myers Adv.

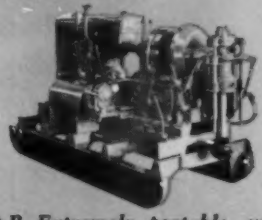
Yuba Mfg. Co. ..... *
Geo. C. McNutt Adv.

* Previous Issues

When you're CORE-DRILLING, it's no gamble with these 3 aces in the hole

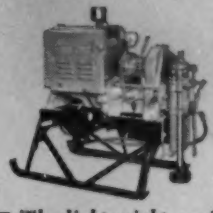
22-HD The rugged, heavy-duty model. Capacity—2000' with EX fittings. Also available as truck-mounted drill or on twin-column mount for underground operation. Bulletin D-28.

1



12-B Extremely portable, weighs approximately 1200 lbs. Capacity—1000' with EX fittings. Also available on twin-column mount with air motor drive for underground operation. Bulletin D-21.

2



No. 7 The lightweight, easily transportable model. Can be taken underground or transported by airplane, boat, or even muleback into remote areas. Capacity—500' with EX fittings. Bulletin D-24.

3

CONTRACT CORE DRILLING *Sub-surface test borings for mineral prospecting, foundation drilling, and grout hole drilling are available on a contract basis. Highly skilled crews and complete stock of core drills, bits, and accessory equipment are maintained at all times.*

JOY Diamond Core Drills When these three "aces" go into the holes, luck no longer is a factor. They are a sure bet to tell you exactly what is down there. And, at Joy, you can find the right "ace" to do the best job for you.

With maximum capacities ranging from 500 to 2000 feet, there are Joy diamond drills applicable to almost any coring job. And they'll do the best job for you. Here's why . . .

EXTREME PORTABILITY Skid mountings, compact design, and rugged construction make it possible to drag Joy diamond drills into some of the most inaccessible locations.

VERSATILITY Because they are available with either hydraulic or screw-feed swivelheads and with a choice of gasoline, electric or air power, Joy core drills can fit into any drilling program without expensive preparations.

Check your drilling needs against this group of outstanding drills. One of them will be suitable to your needs and it will do an accurate, economical job of proving the mineral value of your property. Write today for literature on the machine you need to **Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.** In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*

Consult a Joy Engineer

W&D MS508

JOY

WORLD'S LARGEST MANUFACTURER OF CORE DRILLS AND MOTORIZED DRILL RIGS SINCE 1851

This complete M-S-A mining area coverage gives you the advantage of LOCAL stocks and service

There are few industries where prompt service and "at hand" sales facilities are more vital than in the mining industries. Continuous production is your prime concern—lost time due to delayed shipments, emergency need of repairs or parts for equipment can be avoided by the use of established M-S-A local stocks and trained personnel.

Sixty-eight representatives in twenty-two states and Canada make it their business to see that M-S-A customers have what they want when they need it. Which proves again that our slogan . . . *"When you have a safety problem, M-S-A is at your service. Our job is to help you."* . . . means what it says, wherever you do business. We'll be happy to tell you more about M-S-A Service, and M-S-A products.

MSA
SAFETY EQUIPMENT HEADQUARTERS

When you have a safety problem, M-S-A is at your service. Our job is to help you!

MINE SAFETY APPLIANCES COMPANY
201 North Braddock Avenue, Pittsburgh 8, Pa.
At Your Service: 77 Branch Offices in the United States and Mexico

MINE SAFETY APPLIANCES CO. OF CANADA, LTD.
Toronto, Montreal, Calgary, Edmonton, Winnipeg, Vancouver, Sydney, N.S.

ALABAMA
ARIZONA
CANADA
COLORADO
IDAHO
ILLINOIS
INDIANA
KENTUCKY
MICHIGAN
MINNESOTA
MISSOURI
MONTANA
NEVADA
NEW JERSEY
NEW MEXICO
NEW YORK
OHIO
OKLAHOMA
PENNSYLVANIA
TENNESSEE
UTAH
VIRGINIA
WEST VIRGINIA